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ON THE FUNDAMENTAL NERVOUS PROCESSES IN THE CORTEX OF THE CEREBRAL HEMISPHERES.

I.—The Principal Stages of the Development of the Individual Reflex: its Generalization and Differentiation.

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CONTENTS.

I.—Introduction.
II.—Methods employed.
III.—Observations on the Generalization and Differentiation of Reflexes.
IV.—Fundamental Conditions determining the Origin of Temporary Connections.
V.—On the Origin of the Generalization of Individual Reflexes during the Period of their Formation.
VI.—On the Origin of the Differentiation of Individual Reflexes.
VII.—On the Secondary Generalization of Individual Reflexes.
VIII.—Rapid Formation of New Homogeneous Reflexes.
IX.—Conclusions.

I.—Introduction.

A systematic study of the external manifestations of higher nervous activity—i.e., activity acquired in the course of the individual life and exercised by the cortex of the cerebral hemispheres—was first started by Pavlov with the object of investigating the fundamental laws of the nervous activity of the cortex of the brain. Bechtereff followed Pavlov.

The first systematic investigation on the salivary reflexes was published by Tolochinoff in 1902 [73]. Previously, in 1898, Wulfson [74] had established a series of characteristic symptoms of the so-called psychical secretion of saliva. The positive characteristic features of individual reflexes and their difference from ordinary inborn reflexes were also first pointed out by Tolochinoff. It was, in fact, the work of the

latter which stimulated the further development of the study of individual nervous activity. Later, series of investigations were published annually from the physiological laboratories directed by Pavlov in the Military Academy of Medicine, the Institute of Experimental Medicine in Petrograd, and recently also in the Russian Academy of Sciences.

The investigations of the American psychologists on the psychic life of animals, beginning with the work of Thorndike (1898) [70] cannot be taken into consideration here. Thorndike, as well as Kinnaman and other Americans, as Yerkes [76], Washburn [75] and Franz [32,33]; and Germans, as Kalischer [37, 38] and Szymanski [69]; and French investigators, as Claparède [25], wished to elucidate how far animals can elaborate certain definite movements necessary for life, and to determine if animals recognize various external and internal stimulations as qualitatively distinct from each other. They have endeavoured to test this question by producing in animals the association of a food or a pain stimulus with some other stimulation. For theoretical considerations they directed their attention chiefly to the establishment of the resemblance or difference between the analogous associations of men and animals. This was done in an attempt to explain the psychic life of animals, and to determine the sensory organ which plays the chief rôle in it. Pavlov and his numerous pupils, as Babkin [2], Boldireff [22, 24], Zelioni [78], Perezveig [59], Zavadsky [77], Tzitovich [72], Erofeiva [30], Savich [62], Petrova [58], and many others, have investigated quite another problem, the aim of which was to explain under what conditions and with what constancy and degree of differentiation the connection of an external indifferent stimulus, or of any other kind of stimulus, can be established with such a definite action as the secretion of the saliva in a vertebrate as high as the dog. Further, under what external or internal conditions, and in what direction, that connection may develop. Theoretically they were interested in the purely physiological part of the question, i.e., the nervous processes that take place in the cerebral cortex in the course of the formation and alteration of that connection.

It seems clear that Pavloff and his followers may be regarded not only as the first investigators of the individual activity of the central nervous system who have explained the fundamental laws of its activity, but they have also remained the principal authorities on these questions up to the present.

The principal merit of Pavlov's work is the definition of the funda-

mental conditions necessary for the formation of the individual reflex, as well as the relation of one individual reflex to other reflexes, and to various external or internal stimuli.

In the laboratories directed by Pavlov individual activity is studied by means of the salivary reflex, while in those directed by Bechtereff it is studied by means of motor reflexes.

In both cases the individual reflex is usually established in the following way: Two stimuli are combined repeatedly in such a manner that the second occurs simultaneously with the first, or follows it rapidly. The first stimulus may produce an external reaction, but it may also happen that it is quite inactive or indifferent. It may be either a reiterated sound, or a tactile stimulus frequently applied to a portion of the skin. The second stimulus must always produce a definite external reaction, as the secretion of saliva by stimulation of the mouth by a food substance, or a protective reaction of a limb to electrical stimulation.

After a few such combinations the first stimulus applied alone elicits a reflex similar to that produced by the second. A definite sound, or a tactile stimulus to the skin, may cause a secretion of saliva or flexion of a limb, according to the character of the second stimulus. In Pavlov's laboratory these individually acquired reflexes were originally named *conditioned reflexes* (Tolochinoff, 1902), since their existence depends upon a series of conditions; in other words they alter under the influence of any other condition.

Individual reflexes are opposed to inborn reflexes, the latter being stereotyped species-reactions which are less affected by changes in external conditions; for this reason they were termed *unconditioned*, as opposed to individual reflexes. Bechtereff calls the individually acquired reflexes *combined or associated reflexes*, thus emphasizing the fundamental condition required for their origin, namely, the combination of an indifferent stimulus with an active one.

I do not intend to expose in detail all the results that have been obtained, but it is necessary to refer to the mechanisms of individual nervous activity as established by Pavlov. These are the *temporary connection and the analysers.*

The mechanism of a *temporary connection* is revealed by the fact that any inactive or indifferent stimulus combined several times in succession with an active stimulus which produces a definite motor or salivary reflex, may then itself excite this reflex. A special functional connection is therefore established between the external stimulus and the active portion of the organism.

By means of *the analyser* a decomposition or analysis of the external stimulus is effected; in consequence a temporary connection is not established to all stimuli of a given quality, but only to a definite stimulus. For instance, a reflex may be formed in response to a single musical note, though all other sounds of the same or other instruments evoke no reflex. The whole centripetal part of the reflex arc, including the peripheral receptive organ, the afferent paths from that organ to the cortex, and the part of the cortex into which these afferent paths enter, belong to the analyser. Thus, the visual analyser is composed of the retina, the optic nerve, its prolongation into the brain and the visual region of the cerebral cortex. The term analyser is, however, frequently applied to the cortical section only, because its principal function depends mainly on the cortex. In my further exposition I will use the term in this sense.

According to Pavlov the formation of a temporary connection depends on the fact that a highly excited point in the cortex attracts excitations from other points. But physiology affords, as far as I know, no evidence that any excited point may, as a result of an extremely intense excitation, become a centre of attraction for weaker excitations from other points. The investigations of physiologists have established the fact that any point of the central nervous system may be submitted to such a functional change that it becomes easily excited by weak excitations from other points; none of these authors speak of a power of attraction by the excited point, but only of the existence of a higher degree of excitability in it.

If Pavlov's hypothesis is the chief condition for the formation of an individual reflex, the latter should be easily formed no matter how the indifferent stimulus and the active stimulus are combined, that is, not only when the indifferent stimulus is applied first and is succeeded by the active one, but also when the active stimulus precedes the indifferent. But we learn from Pavlov's work that under the latter condition the formation of an individual reflex encounters great difficulties (Krestovnikov[44A]). To explain it an additional hypothesis is proposed, according to which a state of inhibition is created around the seat of excitation. But this supposition endangers the principal law of the formation of a reflex when the usual combination is employed, since the state of inhibition around a highly excited focus ought to prevent the attraction of excitations from other points to that focus, even when the indifferent stimulus precedes the active one.

During the early period of its formation each new individual reflex

is generalized; for instance, if a salivary-secretion reflex is established to a definite sound of Stern's tone-variator the reflex may be at first evoked not only by this sound, but also by other sounds of the same and of other instruments, and sometimes even by various noises. (Pavlov [56], Mishtoft [45]). To explain the generalization of the reflex Pavlov cites the well-known rule of the irradiation of excitations; "the excitation" he says, "if once evoked in the cerebral hemispheres must diffuse or irradiate throughout the hemispheres. This should be called the first law of excitation." [55]. Consequently, the excitation evoked by an individual stimulus after reaching the cortex and meeting no point of excitation irradiates through its own analyser and even beyond its limits into other analysers. When a point is very strongly excited under the influence of an inborn reflex, this point attracts not only excitations from the focus of the individual stimulus, but also excitations from all other points of the cerebral cortex which are excited by irradiation from the individual focus. Consequently, a temporary connection is formed not only between the salivary centre and the focus of the individual stimulus, but also between the salivary centre and every other excited point. Under such conditions there can be no specific reflex, and the secretion of saliva ought to result not from the individual stimulus only. The generalization of an individual reflex is due to the irradiation of the excitation from the part excited by the individual stimulus.

Irradiation of an excitation is represented in physiology as an active process, as a spread of the excitation from its primary site; this can continue as long as the excitation lasts. The primary excitation results from a stimulus; consequently the irradiation as well as the excitation ceases soon after the cessation of the stimulus. This is undoubtedly true for spinal reflexes as well as for reflexes evoked from the cortex of the cerebral hemispheres by direct stimulation. For instance, if in a dog the excitability of a point of the cortex which normally evokes a flexion of the forelimb is raised artificially by means of strychnine applied locally to it, this point may be excited not only by direct stimuli, but also by the irradiation of excitations from a homonymous point of the other hemispheres, as well as from other motor points. If another motor point is stimulated the response of this and of that to which strychnine is applied occur simultaneously, and both responses cease a few seconds after the stimulation is stopped. The response evoked from the poisoned point, however, persists longer than that from the normal, since strychnine produces a tendency to a strong after-effect. That this

depends exclusively upon the functional state of the poisoned point, and has absolutely no relation to the excitation that irradiates from the normal point, follows from the fact that a similar persisting after-effect may be observed when the poisoned point is stimulated directly (Beritoff [15]). I could cite numerous experiments which show that the irradiation of the excitation spreads over the whole central nervous system in a fraction of a second, and that after the stimulus ceases the duration of the excitation in each point depends entirely on its functional state.

These physiological facts make it impossible to agree completely with the explanation of the generalization of reflexes referred to above. If the generalization is produced during the period of formation of the reflex by the irradiation of an excitation from a point primarily excited by an individual stimulus, and by the connection of this and of other secondarily excited points with the gustatory-secretory mechanism, then the formation of a reflex as well as its generalization must occur when the gustatory stimulus coincides with the individual stimulus. It is known, however, that an individual reflex may also be formed when the gustatory stimulus is applied after the cessation of the individual stimulus. In such cases the interval of time between the two stimuli may be so great that it would hardly be possible to speak of the presence of an excitation remaining over from the individual stimulus. It may amount to two minutes (Pimenoff [60]). Even more significant is the fact that the individual reflex is more widely generalized when the interval of time between the two stimuli is long than when the reflex is established by the simultaneous applications of gustatory and individual stimuli. (Grossmann [36], Dobrovolski [28].)

Differentiation of the reflex.—When the combination of a definite sound with an inborn reflex is repeated, first noises and sounds that differ most from the experimental one, and later those more similar to it, cease to evoke individual reflexes. This differentiation is explained, on one hand, by the concentration of the excitation "in a certain channel, in definite lines and points of the cerebrum" (Pavlov [56]); and on the other hand, by the development of inhibitory processes in the remaining part of the cerebral cortex (Pavlov [52, 53, 54]). The existence of such an inhibition was deduced from the fact that if first an inactive stimulus, and ten seconds or so later an active individual stimulus is applied, the effect of the latter is weakened. Pavlov explains this by assuming that "a certain time must pass, time must be given to allow this inhibitory process to pass off, so that the active stimulation may be able to acquire new strength" (Pavlov [57]).

According to contemporary views the inhibition associated with inborn reflexes is an active process like the excitation; it is provoked by stimulation, it develops and passes off as it, and, like the excitation, it irradiates rapidly from its primary focus into other parts of the cerebrum. (Sherrington [64], Forbes [31], Beritoff [16-21]).

Now let us see whether this phenomenon can be explained by this form of inhibition. First of all we must inquire where is the focus of inhibition. It does not exist; there is only a focus of excitation. This means that the inhibition arises around the focus of excitation. It is said that this occurs in accordance with the special law of contrast of nervous activity. This is a rather peculiar law, according to which the excitation produces inhibition around itself. (Pavlov [56], Erofeieva [30] and others). No such law applies to the inborn reflexes; for instance, the starting of activity in the co-ordinated mechanism of an inborn reflex does not impede the occurrence of a similar activity in the mechanism of any other reflex. It is true that if we study the reflexes that act on one peripheral organ we may find that the onset of the one reflex influences another; this is not due to an interaction between the co-ordinated mechanisms of the two reflexes, but is the result of a conflict between innervations issuing from these mechanisms for a common efferent path.

This interpretation is not satisfactory even if we admit that this law of contrast really exists. If inhibition is an active process it may arise around the focus of an excitation when this passes into an active state under the influence of a stimulus, but it cannot last for hours, still less for days and weeks, after the stimulus has ceased. It seems to me that a differentiated inactive stimulus fails to provoke a reflex, not in consequence of inhibition, but for some other reason.

Let us take another example which will, perhaps, emphasize better the insufficiency of the hypothesis of inhibition in the explanation of the phenomena of individual activity. The individual reflex ceases, or is extinguished, if it is reiterated frequently without reinforcement, i.e., without being combined with an inborn reflex. This extinction of the reflex is at present regarded as due to inhibition (Pavlov [55, 56], Zavadski [77]), on the ground that if the mechanical stimulation of two distant points on the surface of a limb evokes a homogeneous salivary reflex, an extinction of the reflex from one of the points leads to extinction of that from the other point. If the second point is stimulated immediately after stimulation of the first, the reflex from which is already extinguished, then the reflex from the second point may be

easily evoked. But if the second stimulus is applied a few seconds later the reflex from the second point appears in a feebler form; in some dogs it is a little weaker after 5 seconds, much weaker after 15 seconds, and disappears entirely after 20 seconds Further, the reflex from the second point is gradually restored and regains its full strength after an interval of 60 seconds. (Kogan [40], Krasnogorski [43]). This is attributed to irradiation and to a concentration of the inhibition that arises in the cutaneous analyser under the influence of the stimulation of the first point.

The cortical representation of the skin of a limb does not occupy in the brain of a dog a larger surface than 2 or 3 cm. It is difficult to believe that inhibition, which like excitation is an active process, spreads so slowly that it requires 5 to 20 seconds to cover a cortical area of 2 to 3 cm. It is noteworthy that the interval of time between the primary extinction of the reflex from the one point and its complete secondary extinction from the other point, varies strongly in different dogs. On some of them it lasts 4 to 5 minutes (Krogan [40]). It was this fact that made one of Pavlov's latest followers suspect the correctness of this explanation (Anrep [1]). It seems clear, therefore, that it is not the well-known physiological process of inhibition, but some other process, that determines the extinction of reflexes.

II.—Methods employed.

The study of complex acquired nervous functions was carried out on dogs. I have used as an indication movements of the limbs and head. Electrical stimuli were employed for evoking the inborn motor reflex on the base of which the individual reflex was established. The wires carrying the current were rolled over a leather strap 0·5 cm. wide, at a distance of 0·5 cm. from one another, and the strap was fitted tightly round the limb so that the electrodes covered a small shaved surface. I used various sounds, the lighting and extinguishing of an electric lamp and the scratching of different spots on the skin, as the stimuli to which the individual reflexes to be acquired should form themselves. Scratching was produced by a special apparatus used in Pavlov's laboratory, which consists of a brush of bristles attached to a rubber bulb. This is connected by a tube with another bulb that is held by the experimenter, and when the latter is pressed the first one expands and brings the bristles into contact with a shaved surface of the skin. This stimulus was applied once every two or three seconds. As unusual

stimuli I employed various sounds, the scratching of different spots of the skin and other stimuli. All parts of the apparatus that made any noise, as the tone-variator, metronome, bell, hand-bell and metal cylinders, were placed behind the dog, out of its sight (fig. 1). The two limbs and the head were connected by means of cords carried by pulleys to myographs, in order to record the movements on a kymograph, as is shown in fig. 1. The dog was placed on a stand in a special room, and the kymograph was in another room where all the work was conducted. The cords from the head and limbs, as well as

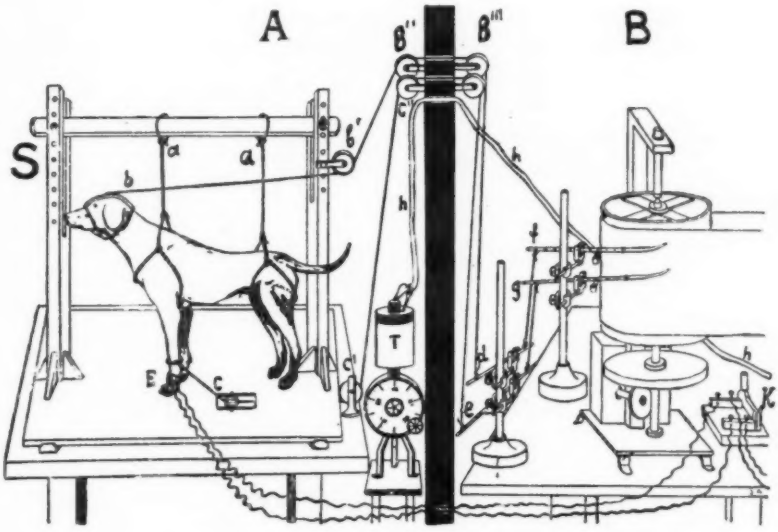

FIG. 1.

Fig. 1.—The arrangements for experiments on individual motor reflexes in dogs. A much simplified figure.

The dog is placed on the stand (S) in one room (A) and the experimenter with the recording apparatus is in another (B). In the figure only the cords from the left forelimb and the head to the myographs (f, g) are shown. The cord passes first from the limb through a slit (e) under the stand, and then over pulleys (c′, c″) into the next room. The cord from the head (b) passes over pulleys (b′, b″, b‴). The levers (d) and (e) serve to reduce the range of the movements. E, electrodes for stimulating the limb; their leads come from the other room from the key (K). Stern's tone variator (T) stands behind the dog; the air is pumped into it from the other room by means of a rubber tube (h), connected with an aspirator, which is not shown in the figure.

those that directed the movements of the metronome and the hand-bell, the electric leads and those for the bell and the electric lamp, the caoutchouc pipes that transmitted the air to the tone-variator and the scratcher, all passed from the working room through narrow openings in the wall (fig. 1). The door had a small glass window to permit observation of the animal. The noise of the kymograph was considerably reduced by placing the clockwork mechanism in a special wooden box lined with felt; when the door was closed it could not be perceived in the dog's room by the human ear, though at certain moments when in a state of high excitability the dog certainly heard it. No other sounds were caused by the experiment, but the dog could hear conversation and movements in the room. The breaker of the primary current employed for stimulation was placed far out in the corridor so that any sound it made could not reach the dog. The arrangements for the experiment are shown in fig. 1.

The experiments were conducted on four dogs. At first I worked for eight months on a large middle-aged male watch-dog called "Bob" (November, 1916, to June, 1917). Then I went on to a young male watch-dog called "Moura." I worked on it for five months (from August till December, 1917). After this I worked simultaneously on two male watch-dogs of middle-age called "Bezoukh" and "Beli." With each of them I worked five months, with "Bezoukh" from February to June, 1918, and with "Beli" from March to July, 1918.

Three of these dogs, "Bob," "Moura" and "Beli," were mild-tempered and would remain calmly in the stand for the usual time of two hours. "Bob" and "Moura" got accustomed to it after a few days, and frequently fell asleep in it. "Beli" only slumbered the first two days, i.e., during the days when the animal is allowed to get accustomed to the arrangements without any experiments being performed. On all the other days throughout the five months it never slept during the experiment. "Beli" behaved from the beginning as though the whole procedure of the experiment was well known to it. "Bob" and "Moura" were continually groaning and restless during the first days, while "Beli" did not groan much and showed little uneasiness from the first. I was able to begin experiments on the formation of the individual reflex on "Beli" as early as the third day, while the experiments on the other two dogs could not be started until the fifth or sixth days.

The dog "Bezoukh" was peculiar; it was very restless, groaned, barked, howled, and tossed about in the stand, trying to free itself

during the whole five months. It is true that later it howled and barked less, but it seldom passed the day calmly. This dog never slept during the experiments, but it soon got accustomed to the stand and even on the third day it jumped into it on its own accord; in this respect it was the best of the dogs.

General Remarks on the Figures.

In all the figures containing tracings the top line records the movement of the head; the upward movement of the lever corresponds to a movement up or to the right, and a downward stroke to a movement down or to the left. The bottom tracing always records the movement of the right forelimb; the upward stroke records flexion and the downward extension. Some of the figures contain another tracing between these two; this records the movements of one of the remaining limbs. When there is one tracing only on the figure it always belongs to the right forelimb.

The first signal line usually records the moment of electrical stimulation, but it frequently also records the time of other stimuli. The other signal lines are not reserved for any definite stimulus; their significance is indicated in the text or on the figures themselves.

The records move from right to left, and the tracings must be always read in this direction. The following conventional signs are used on the figures: F.d, F.s, H.d, H.s, denote the right forelimb, the left forelimb, and right hindlimb and the left hindlimb respectively. The numbers on the signal lines that do not exceed fourteen denote the strength of the stimuli measured by the distance in centimetres of the secondary coil from the primary, while the higher numbers, that is 200 and above, denote stimuli by a musical note of that number of vibrations per second. The letter M. on the signal lines means metronome; L. the lighting and the extinguishing of the electric lamp; B. the bell; S. scratching; C. metal cylinders. The lowest line on all the figures indicates the time in seconds.

III.—Generalization and Differentiation of the Reflex.

To develop the individual reflex I employed the combination of a sound, light, or mechanical cutaneous stimulus with an electrical stimulus to the limb, the latter provoking defensive movements of the limb, in the form of flexion or irregular movements suggesting an attempt at locomotion, with turning of the head and sometimes of the whole body to the stimulated side. Further, the animal generally responded during the first days by a vocal reaction to any important stimulus; it groaned or even howled and barked. I apply the term *individual* to any stimulus to which an individual reflex could be acquired. This stimulus was usually applied 3 to 10 seconds before

the electrical stimulus; it persisted all the time of the latter, and ceased after the cessation of the motor effect evoked by the electrical stimulus. The latter usually lasted 2 to 5 seconds.

The individual motor reflex of the limb developed after two to six combinations. As a rule the individual reflexes of the head, in the form of a special orientation reaction, and of the vocal organ, as a groan or a howl, were obtained some time before the individual reflex of the limbs. The combination was repeated ten to twenty times a day; the intervals between them varied from 2 to 10 minutes, but in some experiments this interval was shorter or longer. The individual reflex of the limb was usually obtained on the first day, and was always present the next day, and even after a further day's interval. At the beginning it always appeared as a slight flexion of the stimulated limb, or as a feeble general movement of the animal, but later, sometimes in the course of a few days, or sometimes only after two or three weeks, the individual motor reflex became limited to the stimulated limb. At the same time its intensity reached its maximal amplitude. This difference in the rapidity of the formation of reflexes was chiefly observed in my dogs in reflexes obtained for the first time; it depended largely on the individuality of the dog. In an excitable animal like "Bezoukh," as well as a less excitable dog like "Beli," the first auditory individual reflexes developed very slowly; in "Bezoukh" after three or four combinations, and in "Beli" after five or six. In the other dogs of medium excitability, as "Bob" and "Moura," the first auditory reflexes were obtained after one or two combinations. We estimate the degree of excitability of dogs by the strength of the motor response they give to various stimuli. Every new reflex of the same limb after the first was established more easily in all the dogs, usually after one or two combinations.

The individual reflex appears in the limbs at different intervals of time after the beginning of the individual stimulus. This interval depends first of all on the combination; the more rapidly the electrical stimulus follows the individual stimulus the shorter is the so-called latent period of reaction. Much depends upon the stability of the reflex and the excitability of the dog during the examination. The latent period generally amounts to 2 seconds to 5 seconds, but it may be shorter or longer. The shortest period for a reaction of the limb to an auditory stimulus was about 1 second. The latent period of a reflex movement elicited in the same dogs by electrical stimuli was 0·15 second to 0·20 second. This shows that under the conditions of

the experiments the physiological period of the individual reaction in dogs, i.e., the time necessary for the spread of the nervous processes through the temporary connections in the cerebral cortex, requires about 0·8 second. The individual orientation of the head always preceded the reflex movement in the limbs; its shortest latent period was about 0·55 second.

At first the individual reflex usually failed easily during sleep, as well as under the influence of various extraneous stimuli. It easily drops out when the individual stimulus is repeated without being combined with an electrical one. But on the stabilization of the reflex the individual stimulus became more potent than all other stimuli of equal strength; during the action of the latter it could evoke strong movements of the limbs as well as an orientational reaction of the head. Further, it was more effective in rousing a dog from sleep than extraneous stimuli of an equal or a greater strength. The constancy and solidity of the reflex increases in time to such a degree that it may be elicited hundreds of times in the course of several days, though the individual stimulus is not combined with electrical stimuli.

Finally, in the course of time the depressing effect of alterations in the arrangements of the experiment as well as of various extraneous stimuli becomes weaker. At first when the reflex is still feeble and unstable the presence of a single stranger is sufficient to cause it to disappear, but later it can be demonstrated though students stand and whisper around the dog. At first the reflex disappeared when one limb was released by removing a strap, but later, even when the dog was free and surrounded by students, the reflex to the individual stimulus would be evoked.

We shall now pass to the stages of development of the reflex. It is well known that in the early period of its formation the individual acquired reflex is generalized, i.e., it can be provoked not only by the stimulus to which it was established, but also by other stimuli of the same and sometimes of other qualities. Its generalization is not, however, always wide enough to allow any stimulus of the same quality to elicit an individual reflex. (Bourmakin [25], Koupalov [42].) In my experiments on the formation of an individual limb defence reflex on "Bob" to a sound of 300 vibrations per second, the reflex was evoked even on the first days only by sounds not exceeding 500 vibrations per second, i.e., less than one octave higher. The reflex could be evoked by sounds of another timbre, as those produced by pipes above 200, but not exceeding 340 vibrations per second. Sounds of the tone-variator that

approximated to the usual sound evoked stronger reflexes. Fig. 2 illustrates the feebler generalization of the reflex during the early days of its formation.

The generalization of the individual reflex to sounds occurs gradually, as was observed by Shevaleff [66] and Koupaloff [42] in the case of individual reflexes to tactile stimuli. Thus, while a motor reflex to a sound of 300 vibrations per second was being established in "Bezoukh"

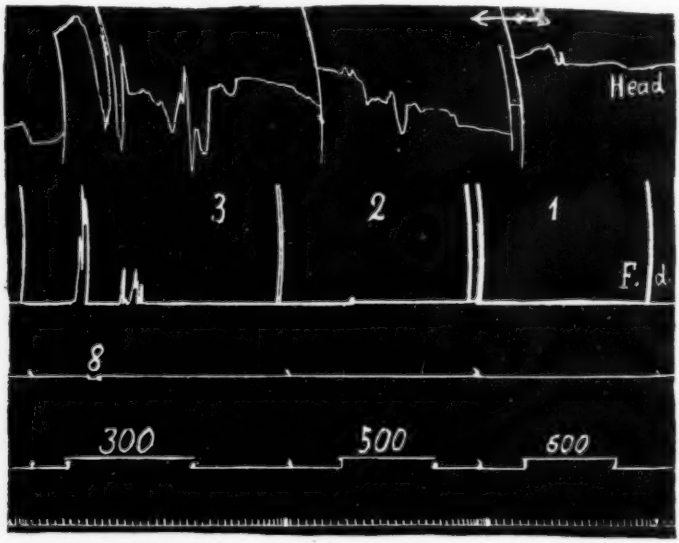

FIG. 2.

Fig. 2. "Bob," October 29, 1916. The first day of the formation of an individual reflex of the right forelimb to a sound of 300 vibrations per second.

The record started after the fifteenth combination with an electrical stimulus. In the first experiment the unusual sound of 600 vibrations gave no reaction. In the second experiment a note of 500 vibrations evoked a reflex consisting of a slight orientational reaction on the head (top curve) and a small defensive shudder of the limb (bottom curve). In the third experiment the usual sound of 300 vibrations evoked a strong orientational reaction and a strong movement of the limb.

it could during the first day be also evoked by an unusual sound of 350 vibrations, but not by sounds of 400 to 500 vibrations. On the next day sounds of 400 to 450 vibrations evoked a reflex, but those of

500 vibrations had no effect. On the fourth day sounds of 500 to 510 vibrations excited a reflex, but those of 550 to 600 vibrations produced none. Only on the fifth day further generalization stopped, and even sounds of 500 vibrations sometimes produced no effect. In one experiment on "Beli" the generalization of the newly-formed reflex reached its maximum on the second day. But there were also cases where the weak generalization that existed during the first few days did not increase, or even become feebler. The generalization of the individual reflex to a given sound of the tone-variator occurred equally to sounds of lower and higher pitch, as has been demonstrated by Eliasson [39]. For instance, when sounds three or four tones higher than the usual one began to evoke a reflex, sounds that were three or four tones lower than the usual note also elicited it.

After some time the generalization of the reflex gradually disappears. For instance, when a reflex was obtained in "Bob" to sounds of 200 vibrations, sounds of another timbre evoked no reflex after the first few days. However, the nearest sounds of the tone-variator, with a difference from half to one-third of a tone (up to 208 vibrations), ceased to produce reflexes in the course of two or three weeks. Therefore the inverse process, the differentiation of the reflex, can go on for weeks.

The differentiation of the reflex depends in a large measure on the character of the dog. In such an excitable animal as "Bezoukh" a high degree of differentiation was never attained to the tone-variator; sounds differing from the usual one by one tone evoked reflexes after many weeks of work. On the other hand a differentiation was obtained on "Beli," a very quiet dog, on the third day. In this case a reflex could be obtained to a sound of 200 vibrations (the first individual reflex), whereas a sound of 225 vibrations, differing from the usual one by one tone, gave no reflex on the third day. On the fifth day a sound of 220 vibrations evoked no reflex, and 215 vibrations produced a feeble effect only. This signifies that even unusual sounds differing from the usual one by less than one tone soon became completely differentiated.

The differentiation of the auditory reflex proceeded equally to sounds higher and lower than the usual one. Thus in "Beli" a reflex was obtained to 288 vibrations, and when all sounds higher than 427 vibrations, i.e., 2·5 tones higher, ceased to evoke a reflex all the sounds that were lower by 2·5 tones, i.e., lower than 213 vibrations, also ceased to evoke it. Later when an unusual sound one tone higher, i.e., one of 320 vibrations, failed to evoke a reflex, a sound of 256 vibrations, which was one tone lower, also produced no effect.

IV.—Fundamental Conditions determining the Origin of the Temporary Connection.

The formation of a reflex on the right forelimb of "Bob" to a sound of 200 vibrations per second may be taken as a concrete case for analysis, and all the processes that took place in the cortex of the cerebral hemispheres during the formation of this reflex may be followed step by step.

The stimulus that becomes individualized—a sound of 200 vibrations—produces an excitation in small areas of the auditory analyser of both hemispheres. Therefore excited foci result from which the excitation irradiates, first through the whole auditory analyser and then beyond it through the whole cortex. The effect of this excitation is, however, much stronger in the auditory analyser than in the rest of the cortex. This is due not so much to the spatial proximity of the focal area to other areas of that analyser, as to the existence of more intimate and more excitable connections between them. For this reason the increase of excitability produced by the sound reaches a higher degree in the auditory analyser than in the rest of the cortex.

The right forelimb receives an electrical stimulus 3 to 10 seconds after the beginning of the auditory stimulus. Although the stimulus was near the threshold (a distance of 10 to 8 cm. between the inductive coils with one accumulator in the primary circuit) in "Bob," judging from its external effects, nearly the whole cortical motor apparatus is excited; the animal moves its limbs, turns its head and its whole body, groans and howls. This shows that the excitation from the cutaneous analyser irradiates throughout the cortical motor apparatus, and through ready-made connections into subcortical mechanisms as well. The excitation of course spreads simultaneously through the whole cutaneous analyser as well as into all other analysers. The greatest effect of the irradiation of the excitation beyond the limits of the cutaneous analyser ought to be in the auditory analyser, especially in that spot directly excited by the sound, which should consequently attain a greater degree of excitability.

When the electrical stimulus ceases the excitation evoked by it disappears rapidly, but the functional change produced, that is the increase of excitability, persists for a long time, especially in the cutaneous analyser, in the motor apparatus and in the auditory analyser. A usual sound repeated a few minutes later encounters an increased excitability in the whole auditory analyser, especially in the region subjected to its direct action. Its effect on the auditory analyser will, therefore, be

greater now than it formerly was, both in regard to excitation and to the rise of excitability. As this excitation spreads beyond the limits of the auditory analyser it must have a specially strong influence on the cutaneous analyser, and on the motor apparatus, the excitability of which is also raised. Further electrical stimuli will, of course, act chiefly on these and on the auditory analyser, and will influence them more strongly than they previously did. They will excite the auditory analyser, not only through the cutaneous analyser, but also through the motor apparatus which is excited directly from this analyser. The excitation of each motor apparatus must certainly irradiate into the whole cortex of the cerebral hemispheres as well as into subcortical motor mechanisms.

Thus the repeated combination of a sound with a pain stimulus to the limb evokes the following effects in the cerebral cortex; in the first place foci of increased excitability are formed in the auditory analyser in response to auditory stimuli of 200 vibrations per second, and in the cutaneous analyser and in the motor apparatus in response to electrical stimuli to the skin of the right forelimb; and secondly, a gradually increasing reciprocal relation is established between these foci.

Let us first consider the statement that the usual individual stimulus from the beginning acts not only on its own analyser but on the cutaneous analyser and on the motor apparatus as well. It is most easy to observe the action of strong auditory stimuli on the cutaneous analyser and the motor apparatus when these are in a state of augmented excitability. If a weak electrical stimulus which evokes a slight flexion is applied to the limb, and an electric bell is in addition rung for a few seconds, it frequently happens that a stronger flexion of the limb is obtained, sometimes after a primary decrease of the existing flexion. When the bell stops the flexion ceases and restarts when the bell is again rung. This phenomenon may be observed when bell and electrical stimulus are first combined, before the formation of any individual reflex in the limb. Such an experiment is illustrated in fig. 3. Even a weak electrical stimulus that produces no effect undoubtedly raises the excitability of the cortical cutaneous analyser and of the motor apparatus of the stimulated limb, and the bell is then sufficient to activate it owing to the irradiation of the excitation from the auditory analyser.

Another example will show that a definite sound may not only produce an excitation of the cutaneous analyser and of the motor apparatus, but it may also lead to an increase of excitability in the latter. Thus after the formation of the individual reflex to an auditory stimulus

raised excitability one minute after the sound. Consequently the rise of excitability in the cutaneous analyser under the influence of the individual stimulus—the sound—is an undoubted fact.

That electrical stimulation influences not only the cutaneous analyser but also the auditory analyser can be illustrated by a series of observations.

I conducted the following experiments in order to determine how electrical stimulation can influence the formation of the individual reflex when it precedes as well as follows the individual stimulus. Electrical stimuli were first applied to the right forelimb; two or three seconds later while the motor after-effect persisted an electric bell was rung for fifteen or twenty seconds; finally, two or three seconds after the bell

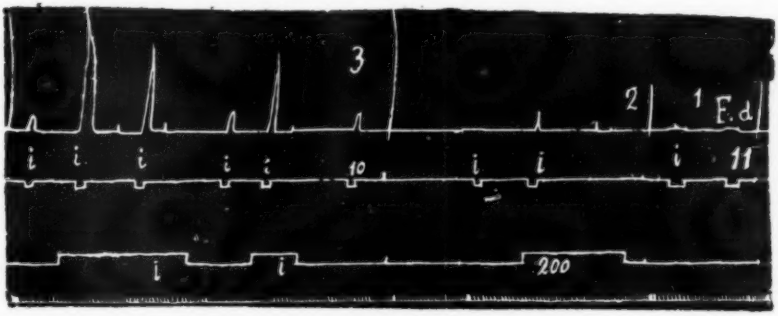

FIG. 4.

Fig. 4. "Bob," December 1, 1916. A reflex movement of the right forelimb in response to a weak electrical stimulus, with and without an individual sound of 200 vibrations. In the first experiment an electrical stimulus of minimal strength, which provoked a slight movement of the limb only, was applied. In the second this stimulus produced a greater effect when applied at the same time as the sound. In the third experiment a stronger electrical stimulus was employed; it also produced a greater effect when it coincided with the sound.

the same forelimb was again stimulated. These experiments were done on "Beli." In this dog when the usual combination was employed—first the sound followed by an electrical stimulus—the individual reflex was obtained on the first day after five or six combinations. Under the new conditions the reflex was obtained on the sixth day after seventy-five combinations, and was found to be stable on the following days.

the application of a weak electrical stimulus to the limb produces a greater effect when it is applied at the same time as the individual sound. This can be seen even better when for some reason the sound evokes no reflex; then an added minimal electrical stimulus produces a strong effect. This may be observed if an electrical stimulus is applied during the latent period of the reflex, for it evokes a very much greater effect than if there were no sound. It also occurs when the sound evokes no reflex, owing to this being extinguished by frequent repetition. In fig. 4, for instance, it is seen clearly how the individual sound, after the extinction of the reflex established in response to it, favours

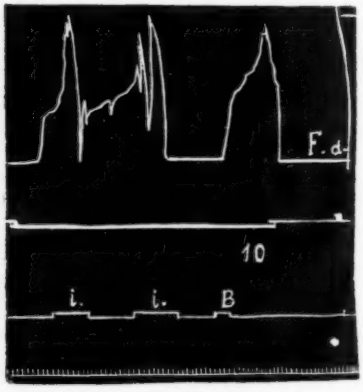

FIG. 3.

Fig. 3. "Moura," September 11, 1917. During weak electrical stimulation of the right forelimb, which evoked only a slight flexion, an electrical bell was rung three times. The first sound which lasted only 3 seconds produced only a cessation of the existing reflex. The second and third sounds which lasted longer produced strong flexion-reflexes after intervals of about 3 seconds; on the third occasion the sound at first stopped the existing after-effect to the previous ringing, but afterwards evoked a new and stronger movement.

the effect to an electrical stimulus. Moreover, the experiments also prove that the rise of excitability caused by the individual sound persists for a long time after the sound, and this occurs independently of the existence of a reflex at the time of the sound; in other words a weak electrical stimulus produces a much greater effect after the sound than before it. In some cases it was possible to determine the presence of

which certainly could happen only in consequence of its combination with a subsequent electrical stimulus; and secondly, if the sound is repeated after the formation of the reflex in a combination with a preceding electrical stimulus, the individual reflex disappears after four or five trials only. To restore it, it is necessary again to combine the sound with a preceding as well as with a subsequent electrical stimulus. At the same time it may be noticed from these observations that a preceding electrical stimulus may in a certain degree favour or even provoke a reflex to the bell, because this individual reflex is obtained immediately after the electrical stimulation only, and is completely unobtainable one minute after it.

The question now arises, why does a preceding electrical stimulus favour the individual reflex? Direct observations exclude a possible influence of the electrical stimulus on the motor apparatus, for even a very weak electrical stimulus which produces only a slight motor effect and is followed by an insignificant rise of excitability in the motor apparatus, nevertheless strongly favours the individual reflex to the sound of the bell. If a stronger motor effect is provoked, or the excitability of the motor apparatus is considerably raised by other means, for instance by a reflex in response to some other individual stimulus, this does not reinforce the reflex to the sound. This may be seen in fig. 5. We may therefore conclude that electrical stimuli produce a favourable effect on the auditory reflex by their action on the auditory analyser, owing to the irradiation of excitations from the cutaneous analyser into the focus excited by the sound of the electric bell.

It is thus seen that when an individual stimulus is combined with electrical stimulus to the limb, there is a reciprocal action between the analyser which receives the individual stimulation on the one hand, and the cutaneous analyser and the motor apparatus which is put into action by electrical stimuli on the other.

V.—On the Origin of the Generalization of the Individual Reflex in the Period of its Formation.

The gradually increasing reciprocal relation between the excited foci finally reaches such an intensity that the excitation irradiating from the auditory analyser begins to evoke through the motor apparatus an external effect similar to that produced by an electrical stimulus; at a sound the animal moves its limbs, head and sometimes its whole body, the movements being accompanied by groans. We know that in this

Its most characteristic feature was the fact that the reflex to the bell was much stronger immediately after the electrical stimulation than a minute or more after it. Moreover, it was completely absent if this interval was longer than one minute. I do not intend to give a detailed description and analysis of this interesting phenomenon, but will confine myself to a few remarks bearing on the question of the action of the electrical stimulus on the auditory analyser. The experiments show that under these conditions the individual reflex was formed by the combination of the sound of a bell with a subsequent electrical stimulus. This is obvious from the fact that this reflex appears after the sound,

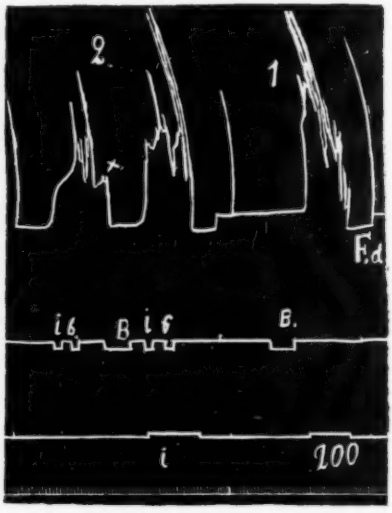

FIG. 5.

Fig. 5. "Beli," April 4, 1918. The twelfth day of the formation of the reflex to the sound of a bell, combined with a preceding and a subsequent electrical stimulus to the right forelimb. In the first experiment the individual reflex of the right forelimb was obtained to the sound of 200 vibrations; immediately after the sound came the bell which arrested the after-effect of the existing reflex, but did not evoke any positive reflex on its own. In the second experiment a usual combination was made. The bell was rung after the same sound of 200 vibrations, associated with an electrical stimulus. Here the bell produced a reflex. It appeared immediately after the bell and is marked by a cross on the tracing.

period the reflex is generalized, i.e., not only the usual sound but other sounds are capable of producing a motor reflex. At the same time, these unusual sounds begin to act more strongly the more they approximate to the usual sound. Now let us see on what this generalized state of the reflex depends.

It may seem at the first glance that it is due to the formation of temporary connections between the whole auditory analyser on the one hand and the cutaneous analyser and the cortical motor apparatus on the other, but an analysis of the observations leads to another conclusion. The excitability of this analyser and of the motor apparatus appears to be very high in the period of the formation of the reflex, and any sound, therefore, excites from it an external effect owing to the irradiation of the excitations. When the cutaneous analyser and the motor apparatus are in a state of high excitability they can be excited not only by the individual stimulus, but also by other unusual stimuli, especially after electrical stimuli which raise the excitability in the cutaneous analyser as well as in nearly the whole cerebral cortex.

Further, it is not certain that 'individual' stimuli can provoke an effect due exclusively to the establishment of temporary connections between the auditory analyser and the cutaneous analyser and motor during the early period of the formation of the reflex. It is quite possible that the cutaneous analyser is excited by unusual as well as by individual stimuli, owing to the general irradiation of the excitations. We may affirm that, as regards the cutaneous analyser and the motor apparatus in this early period, we are dealing with a phenomenon similar to that which occurs when a motor point is poisoned by strychnine; then every stimulus to the periphery produces an effect similar to that which would occur if the poisoned point was separately stimulated. (Beritoff [15].)

I will cite a few examples to prove that any stimulus may provoke a cortical motor reflex without the existence of temporary connections :—

(1) When the individual reflex of the right forelimb to the sound 200 vibrations was fully differentiated in "Bob," that sound provoked an isolated flexion of the right forelimb, the other limbs remaining at rest. All other sounds and noises were ineffective. But if a strong electrical stimulus to another limb, for instance the left forelimb, precedes the sound of 200 vibrations by a minute or even several minutes, that sound provokes a reaction in the left forelimb too, and sometimes this reaction is stronger and appears earlier than that of the right forelimb. This is shown in fig. 6. But if the electrical stimulus to the

right hindlimb precedes the individual sound, the latter also evokes a reflex in this hindlimb. Therefore, the individual stimulus produces an effect on the left forelimb and on the right hindlimb through the respective motor apparatuses which have no temporary connections with the focus of the individual stimulus.

(2) During the period of differentiation of the reflex of the right forelimb to a sound of 200 vibrations other sounds do not evoke

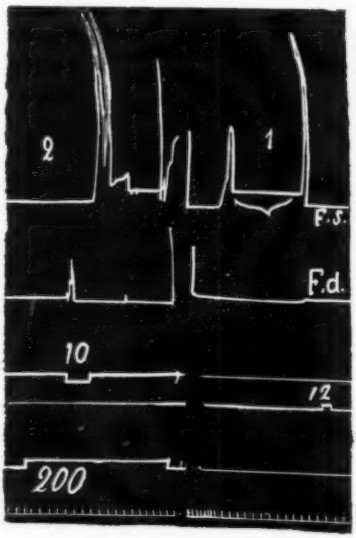

FIG. 6.

Fig. 6. "Bob," November 28, 1916. In the first experiment an electrical stimulus applied to the left forelimb (the second signal line) provoked a flexion of that limb, and in addition a "tearing off" of the electrodes with the teeth. In the second experiment, ten seconds after the first, the sound of 200 vibrations produced a strong effect on the left forelimb instead of the usual effect on the right forelimb. This time the sound was combined with an electrical stimulus to the right forelimb.

reflex reactions, but if the unusual sound follows immediately a strong electrical stimulus to the right forelimb, it may also provoke a reflex which is similar to that obtainable by the usual sound of 200 vibrations. Here the unusual differentiated stimulation provokes an

effect on the right forelimb notwithstanding the absence of a temporary connection with the motor apparatus of that limb.

These facts demonstrate clearly that a reflex motor reaction of a limb can be provoked by individual and by unusual stimuli, though no temporary connection exists, owing to the rise of excitability in the sensory-motor apparatus of that limb.

An increase of excitability occurs also in the auditory analyser around the point which is stimulated by the individual sound. It is possible that the nearer the sounds approach one another the more intimate is the functional connection between those cortical points that receive them. For instance, Bourmakin [25] in Pavlov's laboratory proved that the generalization of the salivary reflex to sounds has a tendency to confine itself to the group of sounds to which the individual sound belongs. Each sound when first employed evoked a reflex if a reflex had been previously obtained to a sound belonging to a group physiologically homogeneous to it.

I may also cite the opinion of Munk [46] that heterogeneous sounds have different cortical representations. Larionoff [44B] in Bechtereff's laboratory tried to investigate this question in detail. By the extirpation of different areas of the auditory analyser in the dog he succeeded in determining that musical sounds are represented in the cortex according to their pitch, i.e., the nearer the sounds stand to each other in the musical scale, the more closely do their respective cortical representations lie to one another. This circumstance explains the fact that in the period of generalization the more the unusual stimulus differs from the usual individual stimulus the weaker is the resulting reflex. Stimuli differing considerably evoke no reflex. It is evident that the less intimate the functional and anatomical connections of the cortical point that receives the unusual stimulus with that of the individual stimulus, the less will its excitability be augmented by the combination of the individual stimulus with the electrical one, and therefore the weaker will be its excitation and the influence of the irradiation from it into the cortical motor apparatus. This fact has an essential importance for the understanding of the gradation of the generalization of the reflex. It has been already shown that in the cortical point which receives the unusual stimulus the excitability increases more rapidly the more intimate its functional and anatomical connections are with the focal point of the individual stimulus. Hence it follows that the nearer the unusual sound is to the individual sound the earlier will it begin to provoke an excitation intensive enough to set into action the cutaneous analyser and the cortical motor apparatus by irradiation.

VI.—On the Origin of the Differentiation of the Individual Reflex.

The temporary connection for a given stimulus is formed gradually and sometimes requires many days of work. As a result of the frequent and increasing irradiation of the excitation into paths between the point of the analyser excited by the individual stimulus and the cortical sensory-motor apparatus of the limb which is later excited by electrical stimuli, intimate connections are established. The stability of these connections depends first of all upon the number of combinations, that is upon the frequency of the irradiation of the excitation into these paths.

It is difficult to understand the nature of these connections, but observations indicate that the spread of the excitation proceeds mainly through them rather than through other paths, and the stronger it is the less it irradiates into other paths from the focus of the individual stimulus as well as from the sensory-motor apparatus. This conception of the mode of irradiation of excitations in the cortex will be made more probable in the further development of this article. One fact strongly in favour of it is that at the beginning of the formation of the individual motor reflex the latter is not restricted to the movement of the one limb. The individual movement is very extensive. The animal moves all its limbs, turns its trunk and head, its breathing is accelerated and it whimpers or groans. This extensive reflex, however, gradually becomes simplified, and is finally limited almost exclusively to the stimulated limb. This fact shows clearly that at first the excitation evoked by the individual stimulus irradiates not only along the paths of temporary connections, but to a considerable extent diffusely through the cortex, where it excites various motor points. Later, however, when the temporary connections leading to the motor apparatus of the stimulated limb are developed, the excitation irradiates chiefly along them.

This mode of irradiation of excitations explains the differentiation of the reflex. As is seen from the description given above, the differentiation of the individual motor reflex coincides with the formation of fully developed connections between the focus of the individual stimulus and the sensory-motor apparatus. Hence it follows that the development of temporary connections represents the turning point in the development of the individual reflex. This is due to the fact that with the development of temporary connections the excitation

ceases to spread diffusely through the cortex. It also leads to a lowering of the excitability in the cortex, both around the foci of the individual stimulus and in the foci excited by electrical stimulation. This tendency of the raised excitability to be limited to the primary foci of the excitation is conditioned by the fact that with each newly repeated combination the excitations from the individual focus will pass more and more through its temporary connections to the sensory-motor apparatus of the stimulated limb, whilst its irradiation into other paths of the cortex will generally decrease. On the other hand, when the temporary connections are firmly established excitations from the sensory-motor apparatus will pass along them and become dispersed less and less through the cortex of the hemispheres. The points of the auditory analyser least intimately connected with the focus of the individual stimulus will first lose their augmented excitability. Consequently, as a reflex to a musical sound is formed, first noises and sounds most unlike it in pitch and timbre, and then those more allied to it, cease to evoke strong reactions. Foreign stimuli of other qualities also fail to evoke reflexes owing to a simultaneous lowering of excitability in all the remaining parts of the cortex.

These are the factors that mainly determine the diminution of the spread of excitations in the cerebral cortex outside the limits of the primarily excited foci. This gradual reduction of the diffuse irradiation of excitations in the cortex may be observed directly. Thus, I found in all the dogs that the motor effect caused by electrical stimulation of an area of the skin was at first very extensive. In the course of time, however, the motor effect of the same stimulus assumed a less extensive form, and finally became confined to isolated flexion of the stimulated limb and a slight orientational movement of the head. It is obvious that the irradiation of excitations was at first very wide; it embraced nearly the whole cortical motor apparatus, but later it proceeded principally along the paths leading to the cortical motor apparatus of the stimulated limb and of the orientational movement of the head. To appreciate fully this phenomenon we must take into consideration the fact that the intensity of the excitation that arises from an electrical stimulus is different in the different paths leading from the cutaneous analyser to the motor apparatus. It is the path to the cortical motor apparatus of the stimulated limb that must be most strongly excited, since this path must be anatomically and functionally the more direct; consequently the irradiation of excitations along it increases and those passing along all the other paths diminish.

But if the stimulus is strengthened, or if the point of the skin stimulated is changed and the irradiation of the excitation in the cortex is consequently augmented, the motor effect again becomes extensive, because in both cases the excitability of the whole cortex is raised.

The motor reactions, therefore, demonstrate very well the fact that the irradiation of excitations from the cutaneous area at first extensive, becomes limited and takes place chiefly along the paths leading to the motor aparatus of one of the stimulated limbs and to that which effects orientation of the head. This, on the one hand, must be due to development of local foci with raised excitability in the area of the sensory-motor apparatus of that limb, and on the other hand to a lowering of the excitability of the rest of the cortex. Thus one definite path connecting the cutaneous analyser with the cortical motor apparatus of the stimulated limb assumes the character of a temporary connection. It is true that this path was concerned in similar activities before the formation of the individual reflex; but then its excitation was on a level with that of many other analogous paths. After the formation of the individual reflex, however, excitations spread exclusively along this path.

From this analysis we may conclude that the intensity of the excitation which irradiates from any point through a given path varies inversely with the intensity of those excitations that irradiate through other paths. The excitation irradiating along a path of a definite excitability is stronger the lower the excitability of all other paths, and therefore the weaker will the irradiation of the excitation through the latter be. In other words, the excitation irradiating from a given point is distributed into paths in proportion to their state of excitability. Consequently the irradiation of the excitation may be termed "interdependent." I do not wish to divide the irradiations of the excitations in the cortex into "dependent" and "independent" classes, for they must in adult animals be always "dependent," since it is impossible to imagine that any excited point of the cortex could be connected with all the other points by equally excitable paths. Only in new-born individuals perhaps are the cortical irradiations not "dependent."

Subcortical irradiations are certainly "interdependent," for with the completion of the development of the central nervous system excitations from each section must pass along one of the paths in preference to others. As a result of this each stimulus evokes a co-ordinated activity of various motor organs from different parts of the central nervous system.

The differentiation of the reflex cannot be wholly attributed to the cessation of the direct action of unusual stimuli on the sensory-motor apparatus, but only to the arrest of the effect of the cruder stimuli which evoked it during the first days of its experiment. The differentiation to unusual sounds which approximate to the individual one is very difficult and requires many days of work. A further analysis is necessary to understand this. The unusual sounds undoubtedly produce a reflex, not only by direct action on the sensory-motor apparatus, but also owing to the temporary connections that have developed. Although these sounds produce an excitation outside the individual focus, they must affect this by irradiation and therefore send excitations through the temporary connection. This is shown by the fact that the primary extinction of the reflex to the individual sound of 200 vibrations as a result of frequent repetition, leads to the disappearance of the reflex to all unusual sounds; and a primary extinction of the reflex to an unusual sound sometimes also leads to its extinction to the individual sound, but as a rule it only weakens it (Eliasson [29], Protopopoff [61], Shevaleff [66]. It is obvious that such a reciprocal relation between reflexes to individual and unusual sounds could scarcely take place were it not for the presence of a common temporary connection. As soon as the repeated unusual sounds cease to evoke a reflex it exerts a negative action on the individual reflex, for during the duration of the unusual sound the individual sound evokes no reflex. This is shown in fig. 7. As will be seen in one of my later studies on extinction, when a reflex is extinguished to one individual stimulus this cannot abolish a homogeneous reflex to another stimulus. Reflexes are called *homogeneous* when they are obtained by a combination with one and the same active stimulus, for instance, with electrical stimulation of the same limb. Therefore, if the unusual sound possessed a temporary connection of its own, its relation to the individual sound would be the same as in the case of two homogeneous reflexes.

Thus, the difficulty in the differentiation of unusual sounds allied to the individual sound is undoubtedly related to the fact that the latter evoke reflexes through the temporary connection of the individual reflex. Consequently, the differentiation of these sounds can occur only when they cease to act on the focus that receives the individual sound.

An accurate differentiation of the reflex is conditioned by the further diminution of excitability around the focus of the individual stimulus. It is evidenced by the longer time and greater number of combinations necessary to attain a maximal differentiation. This

circumstance is related to the fact that the lowering of the excitability must become more and more difficult, because the excitability of the temporary connections, and therefore the intensity of the irradiation that proceeds along them, cannot increase otherwise than in a logarithmetic curve, first rapidly and then more and more slowly.

The state of raised excitability in the differentiating analyser must

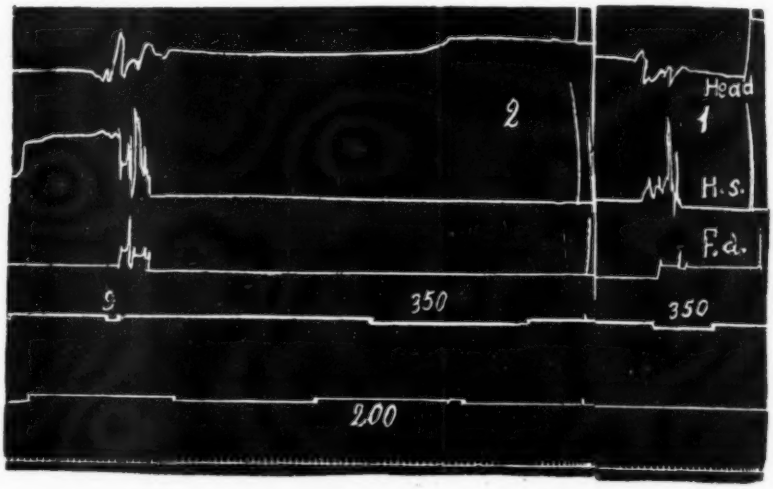

FIG. 7.

Fig. 7. "Moura," August 8, 1917. The third day of work at the formation of a reflex of the left hindlimb (the middle curve) to a sound of 200 vibrations. In the first experiment an unusual sound of 350 vibrations evoked a general movement like the individual sound; in the second experiment, 2 minutes later, the same unusual sound not only elicited no reflex, but it even abolished the reflex to the individual sound. The latter evoked a reflex 23 seconds after the first attempt. The last sound was combined with an electrical stimulus to the left hindlimb.

of course prevent an accurate differentiation of the reflex owing to the impossibility of attaining the necessary lowering of excitability around the focus of the individual stimulus. Indeed it is well known from the work of Pavlov's pupils that in easily excitable dogs the differentiation is attained with great difficulty. (Shishlo [67] and others.) In "Bezoukh," a very restless animal, I could not attain the differentiation

of the reflex in response to one tone higher, which was usually rapidly obtained in other dogs.

Therefore the greater difficulty in the differentiation to an unusual stimulus closely allied to the usual one is due to the fact that it evokes through the temporary connection the reflex to the individual sound. The differentiation to these unusual stimuli is conditioned by the further development of this temporary connection, and above all by the raised excitability in the focus of the individual excitation. It is on account of this limitation or exact localization of raised excitability to the focus of the individual stimulus that unusual stimuli cease to evoke an excitation that could by means of the irradiation activate the individual focus.

Under the conditions referred to above the temporary connection appears to be progressive, i.e., the first stimulus which always precedes the active one produces through the temporary connection the same effect as the second stimulus (in this case a defensive movement of the limb). But we know that the principal condition for the formation of a temporary connection is the reciprocal action between the foci excited by the two stimuli. It is therefore necessary to assume that a regressive as well as a progressive connection must be developed, and that the second stimulus, in this case electrical stimulation of the limb, must produce through the connection an excitation of the foci of the first stimulus and lead to a reproduction of the processes excited by it. The logic of facts requires this. The conditions for the formation of an individual reflex are of such a nature that a simultaneous development of two temporary connections becomes inevitable. The presence of both these temporary connections may be seen in individual reflexes, but no mention has purposely been made of them since at present this does not concern our principal problem, which is the explanation of the origin of the individual reflex and of the mechanism of the principal cortical processes which condition its development. One of the following articles will be devoted to the description and analysis of phenomena which explain the reverse temporary connection.

VII.—On the Secondary Generalization of Individual Reflexes.

Since the process of differentiation of the individual reflex depends upon the lowering of excitability in the whole cerebral cortex, but chiefly around the points excited by the usual stimulus, every circumstance producing an increase of excitability in this spot must reduce the differ-

entiation, i.e., must produce a generalization of the reflex. Thus, at the end of the experiment, after having remained 2 or 3 hours in the stand, the dogs always became restless. Sometimes this was expressed by groans and by turning the head to the door, but often by vigorous general movements. It is during this period, when the excitability of the animal and consequently also of the cerebral cortex is raised, that the reflex becomes generalized, and the generalization is the more extensive the greater the general restlessness until a reflex to all noises is obtained. It is known from investigations in Pavlov's laboratory that the administration of caffeine leads to a rise of excitability and to a generalization of the reflex (Nikiforovski [47]).

A secondary generalization can be easily provoked artificially for a short time. For instance, an unexpected loud sound may be sufficient to provoke a more or less extensive generalization of the reflex for several minutes (Beliakoff [14]). In my experiments the generalization was provoked by a series of electrical stimuli, either with or apart from the usual combination with a sound. The application of a strong electrical stimulus that evokes a general movement two or three times at intervals of 2 to 5 minutes, may be sufficient to produce it. It is obvious that this is due to the stronger stimulus increasing the excitability of the cortical motor apparatus, as well as of the whole cortex. Similar facts have been observed in Pavlov's laboratory (Zelioni [78]).

The differentiation of the reflex, therefore, diminishes as the cortical excitability increases.

VIII.—On the Rapid Formation of New Homogeneous Reflexes.

Another matter of interest is the relatively easy formation of new reflexes by the combination of new individual stimuli with the same active stimulus (Kasherinova [39], Krijanovski [44], Nikiforovski [47], Satournov [63], and others). I have repeatedly investigated this in dogs. Thus, in "Bob," after the formation of two reflexes of the right forelimb to a sound of 200 vibrations and to the light of an electric lamp, I succeeded in obtaining an analogous reflex to the metronome. Previously the metronome had been employed as a strong foreign stimulus. When it was combined with an individual sound or with the light of an electric lamp, the individual reflex did not appear, but a reflex to the metronome was obtained very quickly, and even during the first few days of the experiment it was as intensive as that to the sound of 200 vibrations. At first the only characteristic feature of the reflex to the

metronome was its rapid extinction. No generalization was observed during the experiment. Thus, unusual sounds, as that of a bell or of a tone variator of 300 vibrations, &c., not only produced no reflex, but even depressed the new reflex as well as the old one. In fig. 8 this early period in the formation of the reflex to the metronome is illustrated.

Now let us see on what this rapid formation of the temporary connection of a new homogeneous reflex depends. As the sensory-motor apparatus is common to both the new and the old temporary connections, it may be assumed that it plays the principal rôle in the easy formation of a new reflex. This assumption is made more probable by a series of observations.

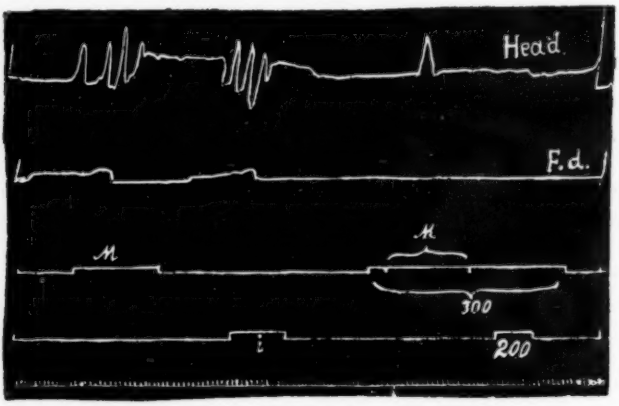

FIG. 8.

Fig. 8. "Bob," November 16, 1917. The first day of the formation of a third reflex of the right forelimb to the metronome. The experiment was recorded after seven combinations. First came the unusual sound of 300 vibrations, during which neither the metronome nor the sound of 200 vibrations produced reflexes. After a certain time each of these individual stimuli evoked similar local movements of the right forelimb (bottom curve) and a similar movement of the head (top curve).

I obtained on "Bob" a reflex of the right hindlimb to a scratching of the lateral aspect of the left hip. The experiment was made after the establishment of reflexes of the right forelimb to a sound, to the light of an electric lamp and to the metronome. A weak electrical stimulus then applied to the right hindlimb in the region of the metatarsus produced an isolated movement not of the stimulated hindlimb, but of the right forelimb, as is shown in fig. 9.

This phenomenon undoubtedly depends on the fact that the sensory

motor apparatus of the right forelimb possessed a higher degree of excitability than the rest of the cortex, and therefore a pain stimulus to any region of the skin activates it first. If the stimulus is a little strengthened a reflex of the hindlimb appears, often accompanied by general movements. But the reflex was not confined to these phenomena, for after the general movement there occurred a long-lasting, isolated flexion of the right forelimb, as is shown in fig. 10. In this case, of course, the effect of the stimulus depended on the excitation of the corresponding cortical motor area of the hindlimb, as well as on the excitation of other areas, and especially of the motor points of the right forelimb.

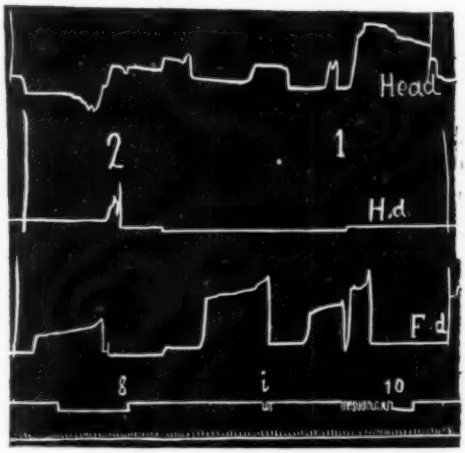

FIG. 9.

Fig. 9. March 18, 1917. A reflex to a weak electrical stimulus to the right hindlimb. In the first experiment a minimal stimulation of this limb produced only a feeble flexion of the right forelimb, in which the individual flexion-reflex was obtained. In the second experiment a more intense stimulation evoked first a short flexion of the stimulated limb (middle curve), and then a persisting flexion of the right forelimb.

Here the combination of scratching the left hip with electrical stimulation of the right hindlimb evoked primarily an individual reflex on the right forelimb. This reflex undoubtedly resulted from the establishment of temporary connections between the cutaneous analyser to which the impressions excited by the scratching came, and the sensory-

motor apparatus of the right forelimb. The scratching only later evoked general movements, followed by an isolated flexion of the forelimb. This is shown in fig. 11.

It is clear from these experiments that the first part of this reflex, composed of general movements, is newly formed by the sensory-motor apparatus of the hindlimb. On the other hand the second part, the isolated flexion of the forelimb, ought to represent the reflex that developed through the sensory-motor apparatus of the forelimb as a result of the first combinations. It might be assumed that the scratching

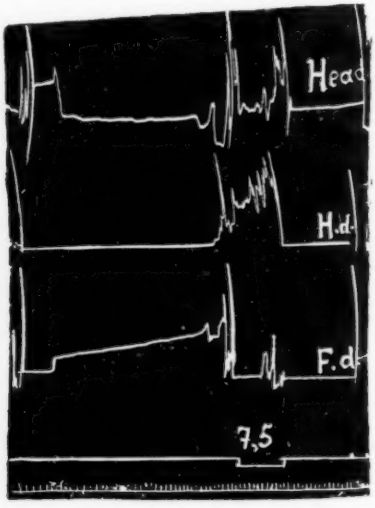

FIG. 10.

Fig. 10. "Bob," March 26, 1917. A reflex of the right hindlimb to a strong electrical stimulus. At the moment of stimulation a strong reaction of the right hindlimb (the middle curve), and after the stimulation a vigorous persisting movement of the right forelimb (bottom curve).

evoked flexion of the limb in consequence of the generalization of the already existing reflexes of the forelimb, but facts point to another explanation, for there was no generalization even to unusual sounds. The bell before and after the experiments with the scratching, for instance, not only evoked no reflexes, but it even abolished the old reflexes as well as the new one to scratching (see fig. 12).

The difference in the stability of the two parts of the reflex is very characteristic; when repeated uncombined with electrical stimuli the

first part disappeared much earlier than the second. This can be seen in fig. 11. Moreover the reflex to scratching persisted till the next day only in the form of an isolated flexion of the forelimb. The relation of this or that part of the reflex to foreign stimuli is also not identical. During the unusual stimulation the scratching produced no general movements, or movements of the right hindleg, while simple flexion of the forelimb always initiated the reflex.

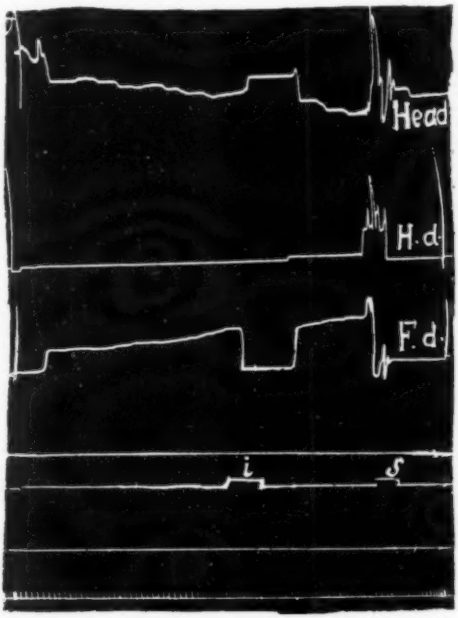

FIG. 11.

Fig. 11. "Bob," March, 1917. The extinction of the reflex to scratching the left hip. At first the scratching evoked a vigorous general movement and then an isolated flexion of the right forelimb. The second stimulus, 10 seconds later, evoked a persisting flexion of the forelimb without any previous general movement.

From all these facts it may be concluded that the temporary connection established in connection with the already elaborated part of the old reflex arcs, that is with the sensory-motor apparatus of the right forelimb, not only develops earlier but may also be much more stable than other temporary connections formed completely anew.

All these facts indicate that the facility in the formation of a new homogeneous reflex depends chiefly on the functional state of the terminal points of the temporary connection, which in this case is the cortical sensory-motor apparatus. The more this apparatus has been prepared by previous work the easier becomes the development of a reaction and the formation of a temporary connection.

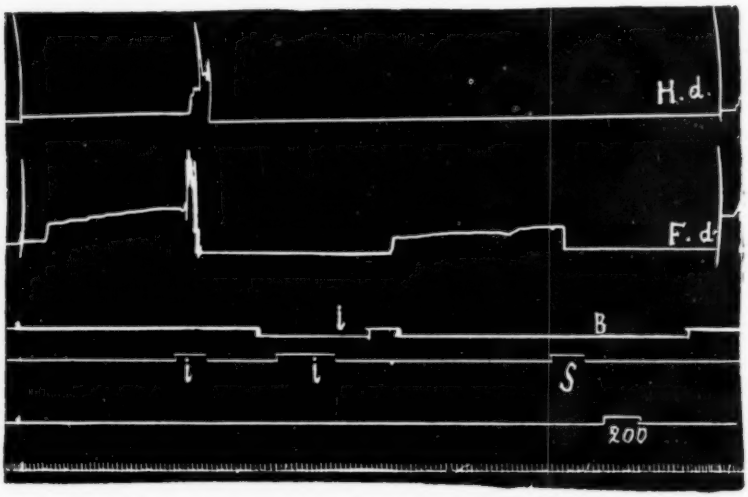

FIG. 12.

Fig. 12. "Bob," June 26, 1917. Scratching the left hip simultaneously with and after the unusual stimulus of a bell. On the first combination of scratching and the bell, the scratching provoked only an elevation of the right forelimb. In the second experiment scratching evoked no reflex at all. Twelve seconds after the ringing of the bell scratching excited a general movement followed by an elevation of the forelimb.

IX.—SUMMARY OF CONCLUSIONS.

The analysis of the development of temporary connections and the generalization and differentiation of individual reflexes allow us to draw the following conclusions:—

(1) The existence in the cortex of foci of raised excitability and of reciprocity between them owing to stimuli acting simultaneously on them, determines the formation of temporary connections.

(2) The initial point of the temporary connection is of little importance for the rapidity of its formation. This depends on the final point

of the temporary connection in our experiments on the sensory-motor apparatus. The reflex is obtained more easily the more the final point is prepared by previous activity, that is the higher its excitability and more accurately localized it is.

(3) The generalization of an individual reflex to unusual stimuli depends on the one hand on the presence of cortical foci which are highly excitable owing to the action of repeated individualized stimuli in combination with electrical stimuli, and on the other hand on a general increase of excitability of the whole cortex of the hemispheres. It is on the latter that generalization depends during the formation of the individual reflex, as well as when it occurs later.

(4) During the period of generalization unusual stimuli differing widely from the usual one evoke the usual reflexes in consequence of a direct irradiation of the excitation into the cortical apparatus that represents the final point of the developing temporary connection, which in our experiments was the sensory-motor apparatus of the stimulated limb. More allied unusual stimuli provoke a reflex by means of temporary connections, owing to the irradiation of the excitation into the cortical focus of the individual stimulus, which is the initial point of the temporary connection.

(5) The differentiation of the reflex is conditioned by the gradual lowering of the excitability of the cortex outside the reciprocally acting foci. This is due to the development of the temporary connections being associated with an augmentation of the irradiation of the excitation into the paths of the temporary connections, and into some inborn paths that lead from the sensory area to the motor apparatus of the stimulated limb, and to that of the orientational reaction of the head. In consequence of the lowering of the excitability in the cortex unusual stimuli cease to evoke a reflex, because the weak excitations that they provoke in the cortex are incapable of affecting by irradiation the local excitable foci, that is, the initial and the final points of the developing temporary connection.

(6) The irradiation of an excitation through the cortex of the cerebral hemispheres proceeds according to the principle that the more it irradiates into highly excitable paths the less it will irradiate into less excitable paths. We may describe this as " interdependent irradiation." Such " interdependent " irradiation of excitations is not peculiar to the cerebral cortex ; it occurs in the irradiation of spinal excitations. But in the latter case the paths of the irradiation are determined by the inborn organization of the central nervous system, while in the former they are developed during the course of individual life.

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"PARATRIGEMINAL" PARALYSIS OF OCULO-PUPILLARY SYMPATHETIC.

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THE so-called syndrome of Horner has, as is well known, got its name from a case of paralysis of the cervical sympathetic described by Horner in the year 1869, in which the clinical symptoms were ptosis, miosis, enophthalmos and hypotonia of the right eye; there were also hyperæmia and moistness of the skin of the same side of the face. Even before Horner, paralysis of the cervical sympathetic was not wholly unknown; Willebrandt, Gairdner and Ogle had already described similar cases, and Claude Bernard had determined the physiology of the cervical sympathetic. Since Horner's case a large number of others have been described in which the same symptoms were present and anatomical lesions were found which affected the sympathetic fibres to the face.

Without going into details I shall briefly recapitulate the anatomy of these fibres. The cervical trunk (fig. 1) takes origin in the cilio-spinal centre between the sixth cervical and the fourth dorsal segments of the cord. The fibres run from here through the rami communicantes to the upper dorsal ganglion, and through the ansa Vieussenii and the cervical trunk to the upper cervical ganglion. Some of the fibres accompany the external carotid artery to the skin of the face, but the oculo-pupillary fibres reach the base of the brain with the internal carotids, as the plexus caroticus internus. Here some of these fibres run as fine filaments to the Gasserian ganglion and join the first branch of the trigeminal nerve, others accompany the oculo-motor nerve (fig. 2). Those that join the trigeminal nerve pass through the naso-ciliary and long ciliary nerves to the eye and innervate the dilator pupillæ, while the filaments which join the oculo-motor nerves supply the involuntary superior and inferior palpebral muscles. On their way through the carotid canal some fibres probably pass by way of the deep petrosal nerve to the spheno-palatine ganglion and innervate the orbital muscle.

The clinical syndrome of Horner may result from a lesion at any place in the course of these fibres, but the completeness of the syndrome varies with the localization of the lesion. When the cervical trunk is

injured all the symptoms are usually present; they are less complete when the lesion involves the spinal cord. It must be also mentioned that the same symptoms may be due to a lesion of the lateral columns of the spinal cord above the cilio-spinal centre, and it seems as though the sympathetic oculo-pupillary functions may be affected by brain lesions also. Schmidt-Rimpler has seen the characteristic signs associated with disease of the optic thalamus, and Nothnagel observed them in cases of central hemiplegia.

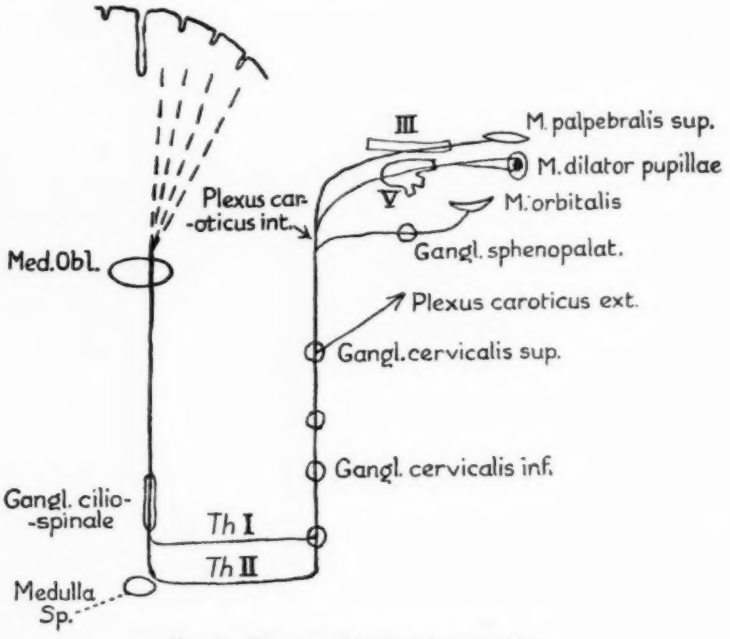

FIG. 1.—Diagram of the cervical sympathetic.

Peripheral lesions of oculo-pupillary fibres have been described. Nieden [6] has recorded right-sided ptosis, miosis, enophthalmos and anidrosis of the forehead and eyelid in a case in which there probably was a lesion of the internal carotid plexus. Metzner and Wolfflin [4] have described lesions of the sympathetic in the carotid canal caused by suppurative otitis media. Bing [1] described paralysis of the sympathetic by herpes zoster, and Nagel [5] has shown that hypotonia and miosis may accompany inflammation of the cornea.

I shall describe here some cases of paralysis of the ocular sympathetic in which lesions could be localized to a limited space, the situation of which justifies the designation "paratrigeminal" paralysis of the sympathetic. The first of my cases has already been published [7]. Since the publication of that paper I have found that Cords [2] and Klauber [3] described in 1917 and 1918 three cases of gunshot wound in which the same symptoms were present.

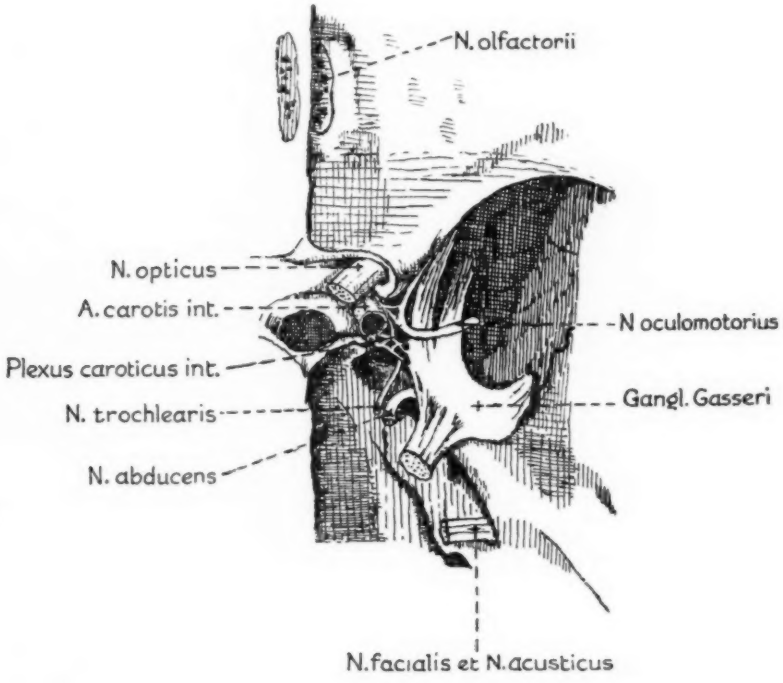

FIG. 2.

Case 1.—On September 5, 1917, a labourer, aged 18, was received in the neurological section of Rigshospitalet, Christiania (Journal, No. 1122, 1917). Since January, 1917, he had suffered from pains in the left eye, which later extended to the left temple and to the whole left side of the head, and in addition radiating pains in the cheek and the teeth of the left upper jaw. His appetite was bad and he sometimes vomited in the morning.

The patient was very thin and pale. There was no difference between the two sides of the face, and no change in perspiration. The left palpebral fissure was not so wide as the right; they measured respectively 7·5 and 9·5 mm.

This diminution of the left fissure was due to a ptosis of the upper lid and to a slight elevation of the lower (fig. 3). The pupils were unequal in ordinary daylight, the right being 5 and the left 3 mm. in diameter; in strong light they were 2·5 and 2·0 mm. respectively. They reacted promptly to light, directly and consensually, but the excursion of the left was considerably smaller than that of the right. They contracted promptly on accommodation and convergence. Both pupils reacted only slightly to painful stimuli, and with a magnifying glass the ordinary range of movement was observed on both sides. Intraocular pressure was 15·5 mm. of mercury in the right, 11 mm. in the left eye (Schiotz). The narrower fissure on the right side gave the impression of enophthalmos, but this could not be demonstrated objectively by Schiotz's exophthalmometer. Examination also revealed normal acuity of

FIG. 3.

vision and visual fields of full extent. The optic discs were normal. The lower jaw deviated to the left when he opened his mouth. There was no paralysis of the trunk or limbs, and co-ordination, sensation and the reflexes were all normal. The urine contained no albumen, sugar, pus or blood. A radiogram of the head showed no anomaly, and the Wassermann reaction was negative in the blood.

During his stay in hospital he suffered with headache and vomiting, and had severe pains in and about the left eye, in which there was an excess of tear secretion. From time to time he complained of diplopia, but we were unable to determine definitely which muscle was affected; we had the impression that there was a variable paresis of several muscles.

The ocular symptoms present seemed to be due to a paralysis of the cervical sympathetic. To test this different drugs were instilled into the eyes

and the following results were obtained: At the beginning of the experiments the size of the pupils were: right, 4·0; left, 2·5 mm.

	Right		Left
After 1 per cent. cocaine ..	7·0 mm.	..	2·5 mm.
,, 1 ,, atropin ..	8·5 ,,	..	8·0 ,,
,, 1 ,, eserine ..	1·7 ,,	..	1·5 ,,

Consequently the peripheral branches of the oculomotor nerves were intact on both sides, but the left sympathetic did not react to 1 per cent. solution of cocaine. There was therefore a sympathetic pupillary paresis. The fact that the left pupil remained somewhat smaller than the right after the instillation of atropine and eserine must be due to the absence of dilator tonus on the left side.

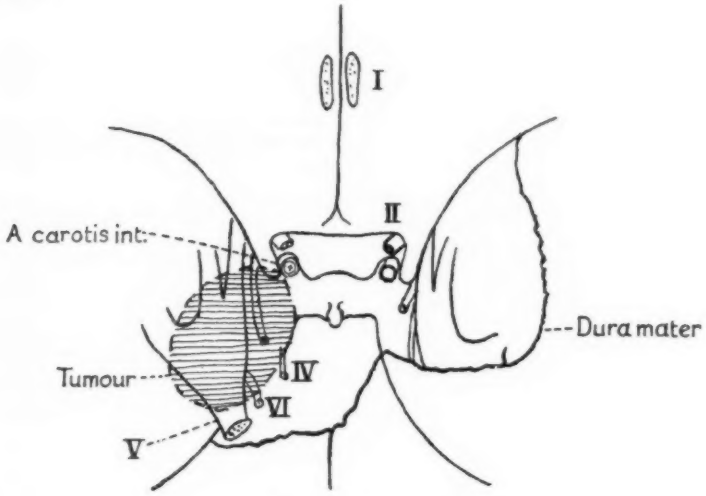

FIG. 4.—Case 1. Position of the tumour.

The case thus presents the following symptoms: vomiting, pains in head and neck which radiated beyond the trigeminal region, and epiphora of the left eye. Objectively there was a paresis of the left fifth nerve and paralysis of the left ocular sympathetic, without vaso-motor and trophic changes, and without evident enophthalmos. There was also diplopia.

There was no evidence of enlarged glands in the neck or of other cause of compression of the sympathetic trunk here. On the other hand the paresis of the left pterygoid muscles, the epiphora of the left eye and the radiating pains in the left trigeminal area, pointed to disease at the base of the skull. If this lay in such a position as to involve the delicate sympathetic fibres from the internal carotid plexus to the third and fifth cranial nerves, all the symptoms could be explained by a single lesion. The fact that there was no hyperæmia

of the skin or disturbance of sweat secretion on the face may be explained by the fibres subserving these functions leaving the sympathetic trunk lower down (fig. 1). But too much importance must not be attached to this fact, for the clinical appearance of paralysis of the sympathetic is not always complete.

In this case our focal diagnosis was a lesion situated near the Gasserian ganglion on the left side, between it and the internal carotid artery.

During his stay in hospital the patient grew worse and died of a rapidly advancing pulmonary tuberculosis. The post-mortem examination revealed nothing extraordinary in the brain or its membranes, but after the dura had been removed from the middle of the fossa of the skull a greyish tumour with a reddish tint and of rather firm consistency was seen on the left side (fig. 4). Medially it reached the hypophysis, laterally the Gasserian ganglion, which when compared with that of the other side appeared raised and displaced outwards. In front it extended approximately to the fissura orbitalis superior and backwards to the posterior limit of the middle fossa of the skull. The oculomotor nerve extended over the tumour, the abducens was displaced laterally and disappeared between it and the Gasserian ganglion. The trochlear nerve ran considerably more medially and seemed to lie underneath the tumour. The growth covered the internal carotid artery.

Microscopical sections of the new growth showed it to be a tumour consisting of tightly packed cells of no typical character. The nuclei of the cells were large, round or polygonal, and poor in chromatin ; the protoplasm was scanty and the cells were usually not very well defined. A series of sections were taken in such a plane that each passed through the Gasserian ganglion so as to permit a clear orientation of the mutual relations of this structure and the tumour. The medial, middle and lateral parts of the Gasserian ganglion were infiltrated and the whole ganglion was displaced lateralwards, together with the abducens nerve and the motor branch of the trigeminus. The trochlear was displaced medially and lay close to the carotid artery. The latter was completely surrounded by the growth, except a small portion of it adjacent to the hypophysis which the tumour never quite reached. The numerous large and small sympathetic fibres passing between the carotid artery and the Gasserian ganglion were completely surrounded by the tumour, which in places seemed to infiltrate them. The trochlear and abducens nerves, as well as the motor root of the trigeminus, which could be easily recognized by the coarse myelin sheaths of their fibres, were also infiltrated by the growth. The sympathetic fibres, the myelin sheaths of which were either absent or very thin, lay embodied in the tumour and were infiltrated by its cells to such an extent that the fibres remaining could be scarcely distinguished.

In the intestines and in both lungs tuberculous changes were found. There were no tuberculous glands in the neck, nor any glands near the cervical sympathetic which might compress it. The sympathetic trunk was dissected, but no morbid changes could be found in it. The tuberculous disease of the lungs did not apparently spread to the ganglion stellatum or to the sympathetic

ganglia of the neck. Microscopical sections from the stellate and the inferior cervical ganglia, as well as from the sympathetic trunk, showed nothing abnormal. The tumour was regarded as an endothelioma.

Epicrisis—This case presented the symptoms of an oculo-pupillary paralysis of the sympathetic with a typical localization. The cause was found to be a tumour which injured the nerve filaments connecting the carotid plexus with the trigeminal and oculo-motor nerves. The clinical syndrome produced by this injury does not correspond to that ordinarily found in lesions of the cervical sympathetic, only the fibres destined for the eye being damaged. The explanation of this fact is that these sympathetic fibres were injured where the branches to the other organs of the face had already parted from them. Paresis of the pterygoid muscles, radiating pains in the face and epiphora, indicated a lesion of the trigeminal nerve in addition to paralysis of the sympathetic. The occurrence of these trigeminal symptoms was to be expected from the localization of the lesion, and from the fact that the growth infiltrated the Gasserian ganglion. The diplopia was due to infiltration of the abducens, trochlear and oculo-motor nerves where they all lie fairly close together.

The coincidence of oculo-pupillary paralysis of the sympathetic and trigeminal symptoms makes the designation "paratrigeminal," which was suggested to me by Professor Monrad-Krohn, appear suitable for this type of sympathetic lesion.

The symptoms observed in this case are not isolated, and perhaps not even rare.

Case 2.—(Demonstrated by the author in *Oftalmologisk Fordlening of Kristiania*, on March 3, 1920).

The patient, a man aged 65, developed an inward squint of the right eye six months ago. At the same time he noticed that the right eyelid "had fallen a little." He suffered with neuralgic pains round the right eye and in the right part of the forehead, and there had been some epiphora. Lately he had also complained of headache.

On examination the following changes were found: The right eye was converged and could not be moved outwards; its downward movement was also defective. The right palpebral fissure was smaller than the left, chiefly owing to a ptosis (pseudo-ptosis) of the upper lid and perhaps also to an elevation of the lower lid. The pupils were unequal in light of all intensity, the right being smaller than the left. The difference increased when the illumination was reduced.

An affection of the sympathetic, to which these symptoms pointed, was confirmed by instillation of 1 per cent. cocaine; the right pupil scarcely increased in size, while the left widened to 6·5 mm. In control experiments with

homatropin both pupils dilated fairly well, the right one, however, a little less than the left.

There was also a slight reduction of tactile sensibility in the area of the upper branch of the right trigeminal nerve, corresponding to the region to which the neuralgic pains were referred. Otherwise nothing abnormal was found in the face. Perspiration and the vaso-motor state were the same on both sides. There was no enophthalmos, and the tension of both eyes was the same.

Epicrisis.—In this case a paresis of the right fourth and sixth cranial nerves was associated with epiphora, neuralgic pains, and reduced tactile sensibility in the area of the first sensory branch of the trigeminal nerve. There was, in addition, ptosis and miosis on the right side indicating paralysis of some of the sympathetic fibres. Though a post-mortem examination was not obtained we are justified in assuming that the lesion must have lain in the same position as in the first case.

Case 3.—This case was referred to me by Professor S. Hagen.

The patient, a man aged 48, was run over by a motor car. On examination an incomplete syndrome of Horner was found, consisting of ptosis and miosis on the left side. There was also hypæsthesia of the left side of the face, and a paracentral temporal scotoma in the left eye.

Epicrisis.—In this case the symptoms were probably due to a fracture of the base of the skull through the medial part of the right middle fossa. In addition to an incomplete paralysis of the sympathetic, the trigeminal nerve was affected as in the previous cases, but the third, fourth and sixth cranial nerves were intact. Here, however, the optic nerve, which is situated very close to the region in which we assumed the lesions in the other cases to lie, was involved, as is shown by the presence of a paracentral scotoma.

Case 4.—The patient, a man aged 28, attended the out-patient department for eye diseases owing to trigeminal neuralgia on the left side. The pain was limited to the distribution of the frontal and supraorbital nerves. There was a definite sympathetic ptosis on the same side. The left pupil was in lights of all intensity smaller than the right, the measurements being:—

	Right	Left
By reduced binocular illumination ..	7·0 mm.	6·5 mm.
,, ordinary ,, ,, ..	6·0 ,,	5·0 ,,
,, strong ,, ,, ..	3·5 ,,	3·0 ,,
On maximal accommodation ..	3·0 ,,	2·8 ,,

After instillation of 1 per cent. cocaine the following measurements were found:—

	Right	Left
By reduced binocular illumination ..	8·5 mm.	6·6 mm.
,, ordinary ,, ,, ..	8·0 ,,	5·0 ,,
,, strong ,, ,, ..	4·5 ,,	3·0 ,,

There were no vasomotor or trophic disturbances, no enophthalamos and no hypotonia.

Epicrisis.—The difference in the sizes of the pupils in this case was unimportant, but the pronounced inequality that followed the instillation of a 1 per cent. cocaine solution indicates the existence of a paresis of the sympathetic fibres. The only other symptom present was trigeminal neuralgia. This case, therefore, resembles the affection of the sympathetic by herpes zoster ophthalamicus described by Bing. The ptosis suggests a lesion situated posteriorly before the sympathetic fibres from the carotid plexus had joined the oculomotor nerve.

Case 5.—This patient, a labourer, aged 48, was injured by a runaway horse in February, 1923. He was hit in front of the left ear, and was unconscious for several hours after the accident. He remained in bed for eight weeks. The hearing of his left ear was somewhat reduced, the left side of his face was paretic and anæsthetic, and the sight of his left eye was affected.

On examination, no ptosis, lagophthalmos, or enophthalmos was observed. The eyes were pale. The left pupil was smaller than the right in all degrees of illumination, their measurements being :—

	Right	Left
By reduced binocular illumination ..	7·0 mm. ..	5·0 mm.
,, ordinary ,, ,, ...	6·0 ,, ..	4·5 ,,
,, strong ,, ,, ...	3·0 ,, ..	2·8 ,,
On maximal accommodation	3·5 ,, ..	2·5 ,,
After instillation of 1 per cent. cocaine ..	8·0 ,, ..	6·5 ,,
,, ,, 1 ,, homatropin	8·3 ,, ..	8·0 ,,

Ophthalmoscopically the left optic disc appeared pale with sharp borders. The acuity of vision was reduced to counting fingers at 75 cm., and the field of vision was contracted to 10° to 40°. There was a left-sided motor trigeminal paresis, the masseter muscles being much atrophied and the lower jaw deviating to the left. Sensation was diminished in the areas of all the three branches of the left trigeminal nerve. No vasomotor or trophic disturbances were observed in the face, and there was no hypotonia of the eye. A radiogram of the skull showed nothing abnormal.

Epicrisis.—The disturbances in this case were probably due to a fracture of the base of the skull which had passed through the left middle fossa. In addition to a lesion of the second and fifth cranial nerves, there was a paralysis of the sympathetic which, however, involved only the fibres to the dilator. It must therefore be assumed that the lesion lay farther forward than in the other cases, that is, in front of the anastomosis between the carotid plexus and the oculomotor nerve, so that the sympathetic fibres to the involuntary palpebral muscle were not injured.

On looking through the literature I have found that a number of cases of trigeminal neuralgia have been described in which there was also homolateral miosis. Judging from my observations I submit that the majority of these cases were actually due to paratrigeminal lesions.

Summary.—The chief symptoms in the five cases here described may be tabulated thus:—

		Cranial nerves affected	
Case 1.	Sympathetic symptoms ..	V	III, IV, VI
,, 2.	,, ,, ...	V	IV, VI
,, 3.	,, ,, ...	V	II
,, 4.	,, ,, ...	V	—
,, 5.	,, ,, ...	V	II

It is seen that the sympathetic symptoms were accompanied by disturbances pointing to a lesion of one or more cranial nerves. The nerve most constantly involved was the trigeminal; this syndrome has been consequently termed *paratrigeminal.* The anatomical lesion responsible for this paratrigeminal sympathetic syndrome may be assumed to have more or less the same localization as the tumour found in Case 1.

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OBSERVATIONS ON THE NATURE OF THE MUSCULAR RIGIDITY OF PARALYSIS AGITANS, AND ON ITS RELATIONSHIP TO TREMOR.

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PAGE

CHAPTER I.—INTRODUCTION 159
CHAPTER II.—THE ORIGIN OF PARKINSONIAN MUSCULAR RIGIDITY 164
§ 1.—Methods of Investigation 165
§ 2.—The Effects of Intramuscular Injections of Novocain upon Rigidity and upon Voluntary Movement 167
CHAPTER III.—RIGIDITY AND TREMOR DISTINCT AND SEPARABLE PHENOMENA .. 172
CHAPTER IV.—CONCLUSIONS 174
CHAPTER V.—SUMMARY 176
REFERENCES 177

CHAPTER I.—INTRODUCTION.

DURING the past decade the symptom-complex of paralysis agitans has been the subject of close study by numerous observers, and in Foerster's recent and masterly paper [1] the limits of purely clinical analysis have in all probability been reached. The interpretation of the different components of the symptom-complex has also been attempted but with less satisfactory results. This is largely due to a confusion which has arisen between the two distinct problems involved in the localization of symptoms and that of functions, but not less to the fact that our knowledge of the normal functions of the spinal cord, and more particularly of the brain-stem, in respect of the motor activities of the organism, has been too incomplete. So long as we lacked precise information of the various factors concerned in the nervous regulation of movement and of posture, it was clearly impossible to interpret the motor disorders of pyramidal or of extrapyramidal motor diseases in terms of normal function. The work of Sherrington, Magnus and their co-workers, however, has provided us with a mass of precise information on these points, and it is now becoming possible to attempt a physiological analysis of the main motor syndromes resulting from disease of the central nervous system. In so far as the symptom-

complex of spastic paralysis from pyramidal system lesions is concerned, such an analysis has been undertaken by various observers with fruitful results, but that of paralysis agitans and the other extrapyramidal motor diseases still remains to be undertaken from this point of view.

In the present paper the characteristic rigidity of paralysis agitans will be considered in respect of its origin and nature and of its relation to the tremor which so commonly accompanies it. It is hoped to deal with other aspects of the symptom-complex in subsequent papers.

That there are certain essential differences between the rigidity of extrapyramidal and the spasticity of pyramidal system diseases is now generally accepted, and the classification and description of these have been fully considered by Foerster in the paper already alluded to. We may briefly summarize the points of resemblance and of difference as follows: *In spastic paralysis*, as we see it for example in a case of residual hemiplegia, the spasticity is selective in incidence, predominating in the flexors of the upper and the extensors of the lower limb. On passive stretching of a group of spastic muscles, the tonic resistance is maximal at the beginning of the movement, melting suddenly away after the initial stage of lengthening, hence the term "clasp-knife rigidity" sometimes applied to it. It is abolished by posterior root section, that is, by depriving the tonic muscle of its afferent nerve supply. In other words, spasticity is a proprioceptive reflex arising in the tonic muscle itself. It shows the "shortening" and "lengthening" reactions described by Sherrington, the former being seen clinically in the tonic prolongation of the knee-jerk in the spastic leg. It is accompanied by an exaggeration of the tendon jerks, and by a qualitative alteration in the plantar response, which is replaced by the Babinski or dorsiflexion response on stimulation of the sole. It is readily inhibited by intercurrent reflex movements on cutaneous and deep stimulation. The flexion reflex, of which the Babinski response is an integral part, is the example of this transient oversetting of spasticity most familiar to clinical observers. Finally, it is invariably accompanied by a greater or lesser degree of loss of voluntary power in the spastic muscles, that is, by paralysis. In conclusion, these various features are a strong indication of the physiological identity of spasticity with the decerebrate rigidity of Sherrington [17].

The rigidity of paralysis agitans, on the other hand, is diffuse in its incidence throughout the musculature, more particularly that of the limbs, and is equal in intensity throughout the whole range of passive movement. There is still some uncertainty as to whether it is pro-

prioceptive in origin, or can be affected by cutting the afferent nerves from the rigid muscles. In uncomplicated instances it is not characterized by an increase in the tendon jerks, and the plantar response is of the normal type.[1]

It cannot be inhibited by intercurrent reflex movements, such as the flexion reflex, and it is not accompanied by true paralysis. Finally, those reactions familiar to clinicians as "associated movements," which arise as proprioceptive postural reflexes in the various skeletal muscles and act upon the spastic muscles in cases of hemiplegia, are invariably completely absent [16].

A more detailed examination of certain of these characteristics is essential to a complete understanding of the observations to be described. For example, the ready manner in which the spasticity of a hemiplegia is capable of modification under various reflex influences is one of its most striking features. Phasic reflexes, such as the flexion reflexes of the upper and lower limbs, and postural reflexes arising in proprioceptive nerve endings in labyrinths and joints, tendons and muscles (tonic reflexes of Magnus and de Kleijn), are all capable of producing variations in the tone, and therefore in the posture, of the spastic limbs. A description of these has been given in earlier papers, to which the reader must be referred for more complete details [16]. In striking contrast stands the muscular rigidity of paralysis agitans. In a large series of patients who have been under examination for the purposes of the present investigation, no trace of postural reactions acting on the rigid muscles has been found, an observation already made by Simons [14], and emotional stimuli have been equally ineffective. Despite changes in weather conditions, questions of rest or exertion, the rigidity varies scarcely at all from day to day. Exertion and anxiety may cause

[1] While it is accurate to say that the plantar response is commonly of the normal flexor variety in pure cases of paralysis agitans and of other forms of "extrapyramidal motor disease," there are indications that even in these circumstances the functional integrity of the pyramidal system is impaired. Rosenfeld (*Münch. med. Wochenschr.*, 1921, xxxi, 971) has stated that in some "excited nervous states" a latent Babinski response may be brought out by a hypodermic injection of scopolamine, and one already present intensified. In "striate syndromes," on the other hand, according to this author, this result is not obtained, and he believes that the pyramidal and striate syndromes may be differentiated in this manner. However, in the course of investigations into the action of scopolamine in this respect, it has been noted that many cases of paralysis agitans presenting the normal type of plantar response give an unequivocal Babinski plantar response on one or both sides for some three hours after an injection of $\frac{1}{150}$ gr. to $\frac{1}{100}$ gr. of scopolamine hypodermically, the abdominal reflexes persisting undiminished. These investigations will form part of the subject matter of a subsequent paper, but in the meantime it seems possible to say that even in apparently pure examples of paralysis agitans there is a clinically latent disturbance of pyramidal function which can be revealed by this means.

the tremor to redouble in force and to increase in incidence, but the degree of muscular rigidity remains unaltered. *In short, the nervous mechanisms responsible for its maintenance seem wholly inaccessible to stimuli of whatever kind or source.* Further, the rigidity cannot be fully considered apart from the other components of the clinical picture, in the production of which it may be a potent factor. Foerster gives the following list of elementary components ("Grundkomponenten") of the symptom-complex: (1) Tremor which is present during rest; (2) increased plastic tonus; (3) increased resistance to passive stretching of the muscles; (4) a tendency to fixation of the muscle at whatever length is passively imposed upon it (Adaptationsspannung, Fixationsspannung); (5) tonic prolongation of the response to electrical stimulation; (6) absence of irradiation of reflex movements and tonic prolongation of reflex response; (7) absence of postural reactions (Reaktivbewegungen) during complex voluntary movements, and of expressional movements, or tonic prolongation of the latter when present; (8) in all voluntary movements a limitation of range, an absence of spontaneity, a slowness in initiation, performance and cessation, an absence of normal associated movements and of signs of pyramidal system involvement.

The first point to arise from a consideration of this list is that it almost certainly includes phenomena which are simply individual manifestations of more fundamental underlying disorders. As we have indicated elsewhere [15], the study of the cerebellar symptom-complex has been greatly obscured by fallacies arising in this way. At the outset, it is reasonable to suggest that the diffuse, and sometimes intense, rigidity of the musculature may be a prime factor in the causation of loss of associated and expressional movements, and of the slowness and limitation of range in voluntary movement, in a word, of those peculiarities of facies, stance and gait which render the subject of paralysis agitans so striking a figure. This hypothesis appears the more plausible when we consider that the movements which are diminished or lost in this disease, such as the play of expression in the face and the innumerable associated movements which lend life and spring to the bodily activities of the individual, are just those movements which are normally carried out with a minimum of muscular force, and which in consequence might be expected to be the first to be damped down or extinguished when a progressive muscular rigidity takes possession of the musculature. It has been noted, however, that certain of these symptoms may develop in the absence of any appreciable rigidity, and

we cannot therefore regard such a hypothesis as a completely satisfactory generalization of the observed facts.

If we are to determine the nature of the muscular rigidity in paralysis agitans, and to estimate its importance in the production of the other components of the complete symptom-complex, it will be necessary to find some means of abolishing it and of studying the activities of the non-rigid muscles. This brings us back to the fact that we are not altogether certain whether this form of muscular spasm resembles the spasticity of pyramidal system lesions in being a proprioceptive reflex arising in the muscle itself. Paralysis agitans is not a malady for which the operation of posterior root section is particularly well adapted as a palliative therapeutic measure. Nevertheless, there are some references to the subject in the literature. Thus, Leriche [2] [3] treated two cases in this way. The first was a man, aged 53, in whom the disease was of eight years' standing. Bilateral section of the fifth, sixth and eighth cervical posterior roots was performed. The tremor is said to have been diminished, but the rigidity remained unabated. In a second case, the fifth, sixth and seventh cervical posterior roots were bilaterally divided. Subsequently the tremor was less marked in repose, but regained its pristine force and amplitude under the influence of emotion. The state of the rigidity is not mentioned. In 1910, Van Gehuchten (quoted by Leriche) stated that we did not know the effects of posterior root section upon paralysis agitans, and the inconclusive experimental operations quoted above cannot be said to invalidate this opinion. Ramsay Hunt [8] quotes Foerster as his authority for the statement that this operation or the development of tabes in paralysis agitans are without effect upon Parkinsonian rigidity. However, in the paper to which we have already referred, Foerster states definitely that when tabes and paralysis agitans co-exist, or after posterior root section, rigidity disappears. But it is unfortunate that upon neither of these conditions does he give any clinical details.

The literature contains but few examples of the combination of tabes dorsalis with paralysis agitans. Placzek [7], Weil (quoted by Salamonson), and Salamonson [10], have described isolated examples, but from the scanty details provided no final conclusion can be drawn, and these observations, like those quoted on the effects of posterior root section, lack adequate clinical confirmation, and the subject calls for further study.

Chapter II.—The Origin of Parkinsonian Muscular Rigidity.

From the brief résumé we have given it seems clear that a determination of the reflex or non-reflex nature of Parkinsonian rigidity is an important preliminary to any precise analysis of the symptom-complex of paralysis agitans. If a proprioceptive reflex rigidity be in question it should be possible to abolish it by any means that will "de-afferent" the muscle. The operation of posterior root section being out of the question, we are thrown back upon a method adopted for this purpose by Liljestrand and Magnus [4] in the course of some experimental work upon the muscular spasm of tetanus. E. Meyer and Weiler [6] observed that in a case of human tetanus localized to biceps, the intramuscular injection of a 1 per cent. solution of novocain, in a dose of 20 c.c., completely abolished the spasm, leaving the voluntary power and the faradic excitability of the muscle unimpaired. They found that as much as 80 c.c. of this solution could be injected into the tonically contracted muscle without impairing conduction along its motor nerve fibres. Liljestrand and Magnus proceeded to examine the effects of novocain injections on experimentally produced decerebrate rigidity and on the spasm of tetanus in animals. They found that the hypertonus of the decerebrate animal's muscles could be abolished by doses of novocain which did not diminish the indirect faradic excitability of the muscle, as determined by stimulation of the plexus, nor abolish other reflex reactions originating from sources outside the muscle itself. Thus, accesses of tone could be observed in the muscle rendered flaccid in this way by variations in the position of the head (tonic labyrinthine and neck reflexes). That is to say, intramuscular injections of novocain paralyse the proprioceptive afferent nerve fibres of the muscle, but do not, with suitably graded doses, impair the functions of the efferent nerve supply. Similarly, in intact cats, they found that these injections will produce atonia and subsequent slight disorders of co-ordination without diminishing voluntary power. It is clear from these experimental observations that we have in novocain a substance with which we may de-afferent the rigid muscles of paralysis agitans.

In anticipation of the observations to be recorded in detail, it may be stated briefly that the rigidity of paralysis agitans is abolished by intramuscular injections of novocain, of the same strength as suffices to render the spastic muscles of a hemiplegic subject flaccid; that this flaccidity is obtainable without any impairment of voluntary power, or of the indirect faradic excitability of the muscle; that the tremor is unaffected by this means; and that certain striking changes are to be

seen in the voluntary activities of muscles treated in this way. From this it may be argued that the rigidity of paralysis agitans demands for its development and maintenance the integrity of the proprioceptive reflex arc arising in the muscle itself, while the tremor, whatever its nature, is not so dependent and thus differs essentially from the rigidity.

§ 1.—*Methods of Investigation.*

A sterile 1 per cent. solution of novocain was used in all the observations to be described. It is injected, with aseptic precaution, directly into the muscle at its motor point, as indicated in Erb's familiar diagrams. It is beneath this point that the nerve breaks up into its terminal filaments, and during the course of an injection the point of the needle is moved so as to produce as widespread an effect as possible. The amount of solution required varies with the bulk of the muscle under investigation, and the following quantities were found to give the best results: For biceps from 18 to 25 c.c., for each head of triceps and for each of the forearm muscles from 8 to 12 c.c. Smaller quantities produce a very incomplete reduction of muscular rigidity, while with larger ones the motor nerves become affected and voluntary power is impaired. Even in these circumstances, however, there is a period of from ten to twenty minutes during which the afferent nerves alone are paralysed. When the spasm is intense, its complete abolition is not always possible with doses which remain without effect upon motor nerve fibres, and a slight residuum of spasm, possibly due to rue contracture, may persist. The drug acts rapidly and an appreciable diminution of spasm is noticeable on passive manipulation at the end of five minutes. The maximum effect is reached in from fifteen to twenty-five minutes, and some degree of hypotonia persists for about three hours. No ill effects of any kind were noted in any of the subjects under examination. The dosage necessary to de-afferent the muscle without paralysing its motor nerve fibres was determined on three cases of spastic residual hemiplegia, using biceps. The hypertonus associated with pyramidal system lesions is known to be abolished by posterior root sections, and responded accordingly to novocain injections. There was considerable voluntary power of flexion at the elbow in the cases employed, and therefore the question of motor paralysis could be determined. It was found that the quantity of novocain adequate to render a spastic biceps flaccid was also the dose most efficient in abolishing Parkinsonian rigidity in the same muscle of a patient with paralysis agitans.

As a control observation, intramuscular injections of sterile normal saline solution were made into the biceps of two of the subjects upon whom some of the present observations were carried out. They were found to be completely without effect upon the degree of spasm, or upon the voluntary activities of the muscles.

Unfortunately, there is no satisfactory quantitative method of determining the degree of tonic spasm present in a muscle, and passive stretching and shortening of the muscles under examination, or shaking the limb to observe the passive excursion of its distal segments, are the only means available to determine, with any approximation to accuracy, changes in rigidity. However, the change is so striking in some instances that palpation of the muscle, generally a fallacious test, suffices to reveal a marked change in its consistency after a novocain injection.

To determine the functional integrity of the motor nerve fibres, an essential point, the muscle was tested against a spring balance by the method devised by Lovett and Martin [5] to measure voluntary power in cases of poliomyelitis. This was found to give reliable results, constant to within a pound. Originally, the attempt was made to determine the indirect faradic excitability of the muscle before and after injection. A Kronecker coil was used, the indifferent electrodes being placed between the shoulder-blades, the stimulating electrode on Erb's point above the clavicle. The results were found to be very unreliable and varied widely even under constant conditions. The use of moist pad electrodes applied to the skin is beset with sources of error, owing to variations in skin and pad moisture, efficiency of contact and other factors. Therefore, the method proved of no value.

In estimating the effects of novocain injections upon tremor a more difficult problem is encountered. The injection of several adjacent muscles in the forearm without producing some degree of motor paralysis is not always easy. Again, tremor varies so from moment to moment under the influence of emotion, fatigue, comfort or discomfort of the subject while the observations are being made, that a cessation of tremor at any stage is of doubtful significance. However, the result was never in doubt by the end of any given investigation, as the observations and graphic records will show.

The instrument described and illustrated in an earlier paper [16] was employed for purposes of graphic recording.

§ 2.—*The Effects of Novocain Injections upon Rigidity and upon Voluntary Movement.*

Within from five to ten minutes of an intramuscular injection of novocain, the rigidity of the muscle begins to wane. In from fifteen to twenty-five minutes the effect reaches a maximum and the muscle becomes atonic, flabby to palpation and offering no resistance to passive stretching. When the biceps is in question, extension of the flexed forearm encounters no resistance, but once full extension is reached passive

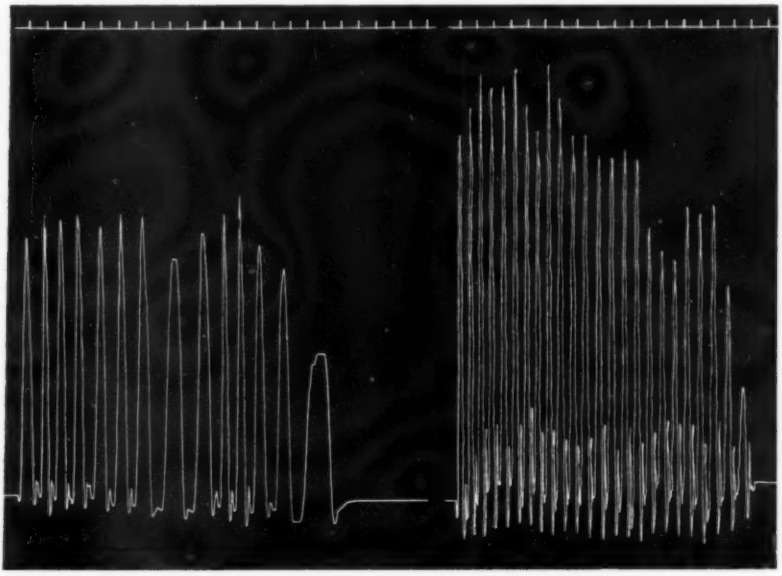


FIG. 1.—Voluntary alternating flexion-extension of the elbow in a boy of 14, the subject of post-encephalitic paralysis agitans without tremor. Moderate degree of rigidity. A, before novocain injection into right biceps; B, fifteen minutes after injection of 20 c.c. 1 per cent. novocain into right biceps. Time in seconds recorded above. Upward movement, flexion; downward, extension. As recorded, one-third amplitude of actual excursion in all records. (⅓.)

flexion is met by the rigidity of triceps, which is thus thrown into striking prominence. In these circumstances the de-afferented muscle is almost or completely painless to pressure, its tendon-jerk diminishes and finally disappears, but voluntary power remains intact.

Even more striking than the disappearance of the rigidity, as tested by passive manipulation, are the alterations produced in voluntary movement. When the subject of Parkinsonian rigidity attempts to make

rapidly repeated alternating movements of flexion-extension of the elbow, wrist or digits, he may be found almost or completely unable to do so. In the former case, a few slow and dwindling movements are made and the limb comes to rest in a position midway between flexion and extension. For many seconds the patient may be completely unable to resume the interrupted movement, and when at last he does so it is again brought to a standstill. When biceps alone, or even more when biceps and triceps together, are de-afferented, alternating movements of flexion-extension at the elbow gain rapidly in speed and amplitude, *pari passu* with the waning of the rigidity, and they can be performed for a longer period before fatigue renders them impossible (fig. 1).

Subjectively also, the patient experiences a new freedom in movements employing the flaccid muscles, and a variety of movements which may for long have been impossible are transiently restored. Thus, one patient was able for the first time in eighteen months to raise a cup to his lips and to drink unassisted after biceps and triceps had been de-afferented in the right arm. If a series of simple voluntary movements involving flexion and extension at the elbow are carried out in these circumstances, the increased speed, amplitude and facility of the arm containing the treated muscles, as compared with those of the untreated limb, are extremely striking. However, in patients in whom tremor is at all prominent, the performance of rapidly alternating movements of flexion-extension at elbow or at wrist increases the force of the tremor to such a degree that when fatigue begins to set in the movement is overwhelmed in the tremor (fig. 5).

The following case record and observation may be taken as typical of the results obtained from novocain injections.

P. M., a man aged 51, with a four years history of paralysis agitans. Onset with tremor and slowness of movement in the left arm. Dragging of left leg followed shortly. Within the past two years the right limbs have become similarly affected. For over a year he has been unable to feed, dress or shave himself unassisted. Has the characteristic gait, stance and facies of paralysis agitans. Shuffling festinant gait with marked propulsion and retropulsion. All movements extremely slow and restricted in range. When taking off his coat, he becomes motionless in the middle of the act, and nearly a minute elapses before he can slowly resume the arrested movements. There is a fine tremor, not constantly present, of the right hand and forearm. Reflexes are all normal. Muscular rigidity is pronounced and approximately equal on the two sides.

February 12, 1924. The patient lies on his back on a hard couch. The right arm is fully adducted and the forearm flexed, so that the hand rests against the front of the shoulder. A strap attached to the hook of a spring balance is

fixed to the wrist. The patient is instructed to keep the forearm in the position described against the force exerted by the observer, who pulls horizontally on the handle of the balance so as to extend the flexed forearm. A reading on the balance is taken by an assistant at the moment that the yielding forearm makes a right angle with the upper arm (cf. Lovett, loc. cit.). The average of three readings is 34 lb. The power of voluntary extension is tested in a similar way. The average of three readings is 20 lb. The patient now sits upright in front of a table with the forearm extended in front of him, the elbow resting on the edge and kept in position by an assistant. A horizontal bar arranged transversely at some distance above the forearm limits the range of flexion of the latter. The extremity of the limb is connected with the recording apparatus of the kymograph. Voluntary alternating movements of flexion-extension at the elbow are carried out with the maximum speed possible to the subject, and of the greatest possible range. The limb is spontaneously arrested in the mid-position after six increasingly slow and dwindling excursions (fig. 2,A).

3 p.m.: 20 c.c. sterile 1 per cent. novocain are injected into right biceps at its motor point.

3.6 p.m.: Rigidity on passive movement is appreciably diminished.

3.10 p.m.: Rigidity still further diminished. Range, speed and persistence of flexion-extension movements definitely increased (fig. 2B).

3.15 p.m.: Biceps is now painless to deep pressure and pinching, and biceps jerk is abolished. Freedom of alternating flexion-extension movements notably increased (fig. 2,C). The tendency to dwindling range of movement is still visible.

3.17 p.m.: 10 c.c. of novocain injected into each of the three heads of triceps at motor points.

3.25 p.m.: Biceps now wholly flaccid, triceps almost so. Record D (fig. 2) taken. The tendency to dwindling range now absent.

3.30 p.m.: Balance reading for biceps 36 lb., for triceps 22 lb. Voluntary movements of flexion or extension at the elbow are as forceful as at the beginning of the observation. The patient can place the right hand on the vertex with fair speed, can lift a cup from table and drink unassisted. The tremor still occurs from time to time with unabated freedom.

The remarkable changes in voluntary movement produced by rendering the muscles employed in them flaccid is well illustrated by these graphic records (fig. 2).

There are, however, one or two other points of interest which have been raised by the observations described. It is scarcely to be expected that the de-afferenting of a single muscle, or of two muscles, should render movement ataxic. Nevertheless, indications have not been wanting to show that a slight degree of sensory ataxy may follow the procedure we have described. Thus, the patient, after de-afferentation of biceps and triceps, or of the former alone, sometimes complains that

the limb tends to "flop" or to "bounce" at the end of extension. In the finger-nose and finger-finger tests carried out with the eyes closed, there is sometimes a tendency to hesitate and to wander before the objective is reached, which is indicative of proprioceptive sensory loss. Finally, as voluntary power begins to wane, after a large injection,

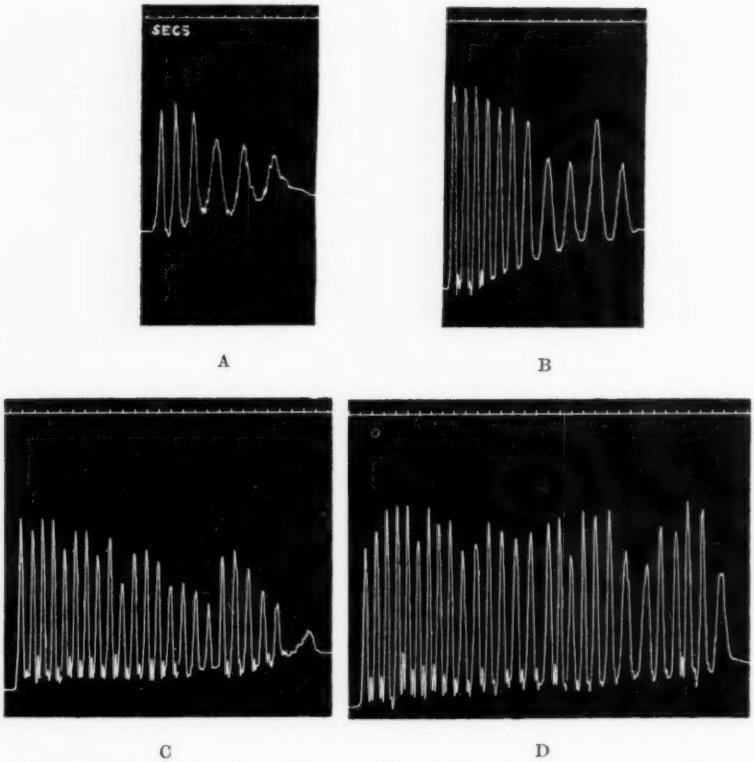
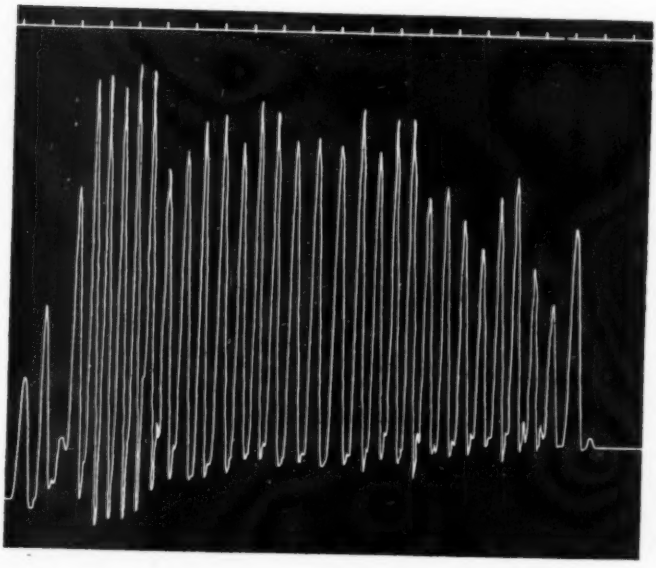
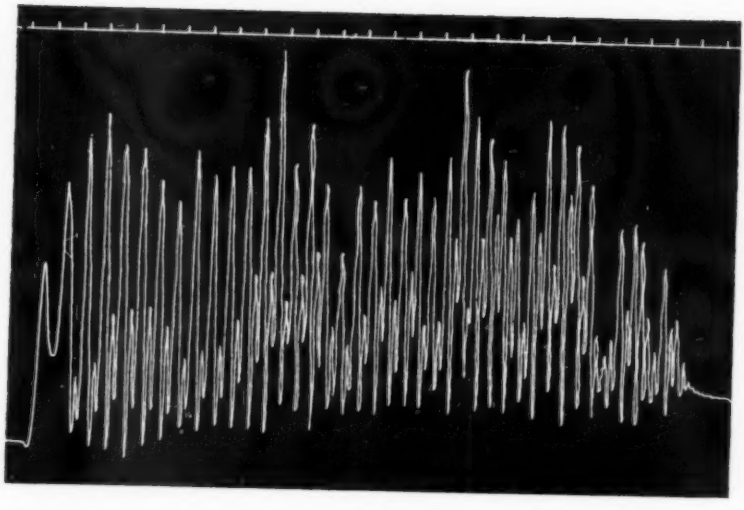


FIG. 2.—Series of records of voluntary flexion-extension of right elbow in case P. M.: A, before injection; B, ten minutes after injection of 20 c.c. novocain solution into biceps; C, fifteen minutes after injection; D, twenty-five minutes after injection into biceps, and six after injections into triceps. Time in seconds recorded above. In A and B the diminuendo character of the movements, in respect of both range and speed, is noticeable. In C, the same feature is much less marked, and after de-afferentation of triceps (in D) it is almost absent. ($\frac{1}{3}$.)

definite disorder of rhythm develops in alternating flexion-extension movements at the elbow. Each component is of different amplitude and is arrested at a different level, giving the graphic record a characteristically untidy appearance (fig. 3).



A



B

FIG. 3.—Voluntary flexion-extension of right elbow in a case of paralysis agitans in a man of 53. Rigidity slight, tremor inconstant. A, before; B, after injection of 25 c.c. novocain solution into right biceps. Some slight but definite loss of power followed injection and movements were abrupt and jerky and of unequal range. (½.)

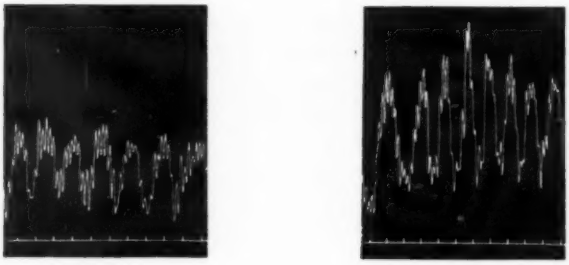
An examination of the various records (figs. 1 to 3) shows that in certain of them there is between the larger excursions, and at the lower or extension end, a smaller excursion. This is instrumental in origin and is due to a recoil of the spiral spring which forms part of the recording apparatus. In slight degree it depends upon the speed of the movement at the moment of its cessation.

But when biceps alone, or both biceps and triceps together, are rendered atonic and insensitive, movement takes on an abrupt ill-regulated character resembling that of cerebellar ataxy (though in but minimal degree), and as the hand reaches the table at the end of extension there is a rebound, which is represented on the records by the small upward excursion between the large movements. The rebound thus indicated is largely an actual excursion of the limb, but is, as we have mentioned, in part of instrumental origin.

We may *summarize* these observations as follows: Intramuscular injections of novocain so graded as to paralyse the afferent nerve fibres in the muscle, and leaving the motor nerve fibres in unimpaired activity, abolish or greatly diminish the rigidity of paralysis agitans. Voluntary movements carried out by the muscles thus rendered flaccid are of greater amplitude and speed, and are less readily fatigued than similar movements carried out while the muscles concerned are still rigid. It seems, therefore, that the integrity of the proprioceptive reflex arc from the muscle is essential to the development and maintenance of Parkinsonian rigidity, and that this rigidity is in all probability of the nature of a proprioceptive reflex arising in the rigid muscle, and finally that rigidity is an important, though possibly not the sole, factor in producing that slowness and restriction of range of voluntary movement which are so characteristic of this malady. However, before we can finally accept the first of these two conclusions a further discussion of the action of novocain upon muscles will be necessary, and this we may defer to a later chapter.

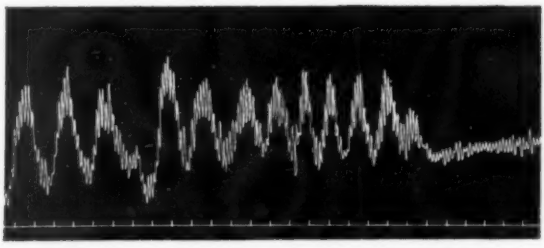
Chapter III.—Rigidity and Tremor distinct and separable Phenomena.

In striking contrast to the effect upon rigidity of paralysing the muscular afferents is the complete immunity enjoyed by tremor in these circumstances. There is always some palpable rigidity in tremulous muscles, and in the case of the familiar hand tremor the extensor and flexor groups in the forearm present a greater or less degree of tonic

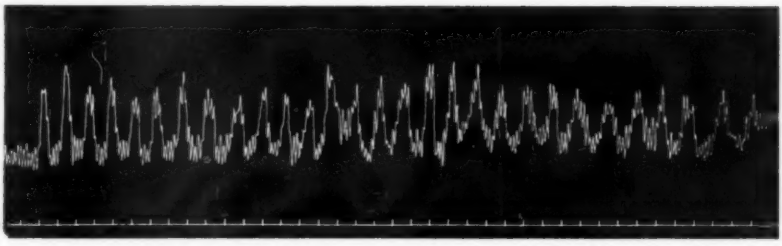


A B

FIG. 4.—Voluntary flexion-extension of wrist before and after eight intramuscular injections (8 c.c.) into flexor and extensor muscles in forearm. Tremor ample and forceful, rigidity of moderate degree in forearm muscles. A, before de-afferentation; B, after de-afferentation. Rigidity in forearm muscles abolished; voluntary movements more rapid and ample, tremor unabated. ($\frac{3}{4}$.)



A



B

FIG. 5.—Voluntary flexion-extension of digits (grasp). A, before novocain injections as above; B, fifteen minutes after injections. In B the movements are more rapid, but not more ample. In both records, A and B, tremor finally swamps movement. Time in seconds above. ($\frac{3}{4}$.)

resistance to passive manipulation, with which is associated the familiar "cog-wheel" phenomenon, giving the observer the sensation of having unmasked a latent tremor. Rapidly alternating flexion-extension of the wrist or digits (grasp-relaxation) is increased in speed and amplitude after the muscles concerned have been rendered atonic by novocain injections, but the tremor persists unaltered. But whereas in the slow laboured movements of the rigid muscles tremor may be present throughout the whole range of movement, and be, as it were, superimposed upon this, after the muscles have been rendered atonic and movement becomes more speedy the tremor may be seen only between the component movements at the end of flexion and of extension (fig. 4).

In other words, tremor tends to disappear while the muscle is rapidly changing its length. This phenomenon is familiar to every clinical observer in the ordinary movements of many cases of paralysis agitans. At rest, and during the active maintenance of a posture, tremor is maximal, but while the involved limb is traversing space it is minimal or may disappear. However, even here, as fatigue sets in, the tremor increases in force and amplitude and with a slackening of the speed of movement the graphic record assumes the form seen in the case of the rigid muscles and the movement is finally swamped by tremor (fig. 5).

We may *summarize* these observations by saying that tremor is unaffected by de-afferenting the tremulous muscles and cannot therefore be a proprioceptive reflex. This finding is in accord with the observation, mentioned by Gowers and others, that a hemiplegia supervening in the subject of paralysis agitans abolishes the tremor during the early and complete stage of the hemiplegia, and indicates that we must look elsewhere than in the proprioceptive system for the origin of tremor.

Chapter IV.—Conclusions.

While it is not proposed to explore fully the bearings of the observations now recorded upon the larger question of the physiological significance of the Parkinsonian syndrome as a whole, yet some further consideration of the immediate questions arising in connection with them is necessary.

We have seen that appropriately graded intramuscular injections of novocain abolish the muscular rigidity of paralysis agitans, and we have assumed that this result depends upon a selective paralysis of afferent nerve fibres in the muscle, so that the muscle is "de-afferented." If

this conclusion be justified we may regard Parkinsonian rigidity as a true proprioceptive reflex. On the other hand, the question of a direct action of novocain upon muscle fibres has been brought into prominence by some recent observations of Schüller [11 12], Riesser [9], and others, and we have to consider whether the abolition of rigidity which we have observed may not be due to such a local action. These authors state that the tonic muscular contraction produced in the isolated muscle-nerve preparation by the action of veratrin, coffein, nicotin and acetyl choline is abolished by the local application to the muscle of weak solutions of novocain in strengths which do not paralyse the muscle on stimulation of its motor nerve. During the course of the investigations recorded in earlier chapters it was found that the injection of novocain into the belly of the muscle was followed by a marked waning of rigidity within five minutes. In the case of biceps and triceps it may be urged that a saturation of the whole muscle by the drug within this period is not probable, and that were a local muscular effect in question we should be able to trace the passage of an increasing flaccidity down the several inches of the muscle between the point of injection and its distal end. Nothing of the latter nature was observed, the rigidity appearing to wane simultaneously and uniformly throughout every part of the muscle. Moreover, in their observations on the effect of novocain injections upon decerebrate rigidity, Liljestrand and Magnus found that, although the muscle was rendered flaccid, yet it was still capable of responding by a tonic contraction to variations in the position of the animal's head (tonic labyrinthine and neck reflexes). This is not what we should expect if a direct action of novocain upon muscle fibres were in question, and indicates that the flaccidity following novocain injections is due in all probability to cutting off of the main source of afferent impulses to the brain-stem mechanisms responsible for the reflex maintenance of tone in the muscle. When other sources are active (proprioceptors of labyrinths and neck) the muscle responds as before by a tonic contraction. All these points go to show that in the present instance an afferent nerve fibre paralysis is in all probability the cause of the abolition of rigidity. Nevertheless, there remains the possibility that a direct peripheral action of novocain upon muscle fibres may play some part, even though a secondary one, in producing the results we have described. Therefore, before we may finally accept Parkinsonian rigidity as a true proprioceptive reflex we shall need conclusive evidence that, like pyramidal spasticity, it can be abolished by the operation of posterior root section.

In conclusion, the writer must express his gratitude to Professor Magnus for much valuable information as to the use of novocain and as to the question of a direct action of the drug upon muscle fibres.

Chapter V.—Summary.

(1) Intramuscular injections of a one per cent. solution of novocain abolish Parkinsonian rigidity, while leaving the voluntary power of the muscle unimpaired.

(2) The rigidity, if not the sole factor in the causation of the characteristic slowness of initiation and performance and the restriction of range of voluntary movements in paralysis agitans, is certainly a very potent factor, since movements employing muscles rendered flaccid by novocain injections are notably more rapid and ample than the same movements carried out by the rigid muscles before injection.

(3) Tremor is completely unaffected by rendering the tremulous muscles flaccid by this means. Therefore, tremor is a phenomenon essentially different in its origin and nature from rigidity, and the widely held view that "tremor is rigidity spread out thin" must be regarded as wholly untenable.

(4) It is extremely probable that the effect of novocain is due to a selective paralysing action of the drug, used in weak solutions, upon afferent nerve fibres. If this be so, the muscle is rendered atonic by being "de-afferented," and Parkinsonian rigidity must be regarded as a true proprioceptive reflex reaction. In this respect it resembles the spasticity which follows lesions involving the pyramidal system, but in other respects, as is pointed out, the two forms of hypertonus differ in important features.

(5) It is possible that the abolition of rigidity is due in part to a local effect of novocain upon the muscle fibres themselves. There is evidence to the effect that novocain can abolish the spasm produced by the action of certain poisons upon the isolated muscle-nerve preparation. Nevertheless, the balance of the evidence points to a paralysis of afferent nerve fibres in the muscle as the cause of the disappearance of rigidity, and consequently to the conclusion that this is a true proprioceptive reflex. More knowledge as to the influence of posterior root section upon this form of muscular rigidity is required before we can regard this point as finally settled.

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A CLINICAL STUDY OF PLASTIC TONUS AS OBSERVED IN A RARE SEQUELA OF EPIDEMIC ENCEPHALITIS.

By DOUGLAS McALPINE, M.D., M.R.C.P.

CONTENTS.

	PAGE
(1) Description of Case	178
(*a*) Motor Power	179
(*b*) Posture and Resting Tonus	183
(*c*) Plastic Tonus	184
(*d*) Reflexes	189
(*e*) Erect Posture	192
(2) Discussion	197

Much interest has been shown recently by clinicians in the subject of decerebration. Extensive studies have been made in man by Wilson [21], Walshe [17], and Riddoch and Buzzard [6], in the light of the phenomena originally described by Sherrington [8] in his classical experiments on the decerebrate animal, in 1898. More recently, Bazett and Penfield [1] have reported their findings in chronic decerebrate preparations of the cat.

The following account is based on clinical observation of a case, previously the subject of an attack of acute epidemic encephalitis. A condition of well-marked plastic tonus existed in the limbs on the right side of the body, and this was associated with muscular rigidity, at times flexor in type and at other times extensor, which, under certain circumstances, closely approximated to that observed experimentally in animals in whom unilateral decerebration in the region of the midbrain has been performed. The left upper and lower limbs showed none of these phenomena, but were the seat of a rigidity typical of Parkinsonism.

Description of Case.

History.—F. C., female, aged 21, first came under observation in November, 1922, whilst under the care of Dr. Campbell Thomson, in the Hospital for Epilepsy and Paralysis, Maida Vale, London, her complaint being one of weakness in the right arm and leg and inability to walk.

The patient stated that she had been quite well until April 18, 1919,

when she suddenly developed double vision; the same night she became delirious. The following day she felt exceedingly drowsy and a constant desire to sleep was present for the next two or three weeks. On April 22, i.e. the fourth day of her illness, on attempting to get out of bed she discovered a weakness in her right leg, and on the following morning her parents noticed that the weakness had now affected her right arm and the right side of her face. She was removed to an infimary, where she remained a year.

Her present condition seems to have gradually developed during her residence in the infirmary, but unfortunately no notes of her condition during this period are available. The patient states that the disability, which now affects her right upper and lower limbs, was present from the earliest days of her illness, but during the years 1921 and 1922, which she spent at home, this became somewhat aggravated. During the period she was under observation in hospital (November, 1922 to September, 1923) her condition remained more or less stationary.

Her past history and family history contain nothing of note.

General Description of Case.

The patient presented a definite Parkinsonian facies, such as is found in cases of this disease following epidemic encephalitis. In addition, her voice was feeble, her speech slow and monotonous, and there was slight sialorrhœa.

The pupils were small, concentrically placed, regular in outline and reacted well both to light and accommodation. The ocular movements were full, except that the power of convergence was slightly enfeebled. There were no nystagmoid movements. The fundi were normal.

The patient's intelligence was fair, but cerebration was somewhat slow. After a year in hospital she never expressed any desire to return home, and her physical condition did not seem to give her any mental distress. Her smile, which was typically spastic (see fig. 7), was easily evoked.

The left upper and lower limbs showed alterations in tone, posture and in the performance of voluntary movements, typical of a moderately severe case of Parkinsonism.

In the right upper and lower limbs there was no trace of a condition similar to that which existed in the limbs on the left side. There was evidence, however, of involvement of the pyramidal tract on this side, a definite extensor plantar response being present. In addition, certain alterations in tone and posture were present in the right upper and lower limbs, which were of extreme interest.

Motor Power.

Head and face.—Voluntary movements of the head on the trunk were full in range and the muscular force was well conserved. The facial muscles showed an increase in tone and lack of power, especially the frontalis, such as are found in the Parkinsonian facies. In addition, on voluntary contraction of the lower facial muscles, a slight but definite weakness of the right lower face became apparent. The jaw movements were carried out somewhat slowly and

feebly. The tongue was protruded well and showed no tremor. The soft palate moved normally.

In the beginning of July, 1923, the patient began to be troubled with diplopia, which continued intermittently for two weeks; during this period there was moderate pyrexia. These symptoms were considered as indicating a flaring up of the encephalitic process. A few days later she noticed that if she closed her eyes she was quite unable to open them, and in order to do this she was compelled to lift one eyelid with the back of her right hand, the other eyelid then rising spontaneously. In September, 1923, this condition still persisted, and on examination the following points were observed: When she had closed her eyes the patient was unable to open them when told to do so. Her efforts were not accompanied by clonic movements of the eyelids. Passive attempts to open the eyes showed that there was a definite hypertonus in the orbicularis oculi which, as further force was used by the observer, suddenly yielded and the eyes opened

The pathogenesis of this form of blepharospasm is of interest. There seemed to be no evidence in this case that would point to an hysterical basis for the condition. A somewhat similar process is present in a certain proportion of cases of Parkinsonism following epidemic encephalitis; but in these patients not only is there usually a tremor during the closing of the eyes, but on attempting to open them again rapid clonic movements can be observed in the eyelids. In the present case there was no perceptible tremor, either on opening or closing the eyes. The present writer has never observed, even in advanced cases of the Parkinsonian syndrome, a complete inability to open the eyes such as existed here. Souques and Blaumoutier [13] have reported a case characterized by spasms of the face, rapidity of speech, tachypnœa, and a progressive diminution in the size of the letters in writing. In addition, their patient on closing his eyes was quite unable to open them voluntarily, and could only do so with the aid of his hand. The eyelids were the seat of a fine tremor. There was no evidence of Parkinsonism, but the authors were inclined to place the lesion in the striatal system. The present case differs from this one as regards the blepharospasm, in the fact that there was an absence of tremor.

The condition seems to depend on a state of tonic contraction in the orbicularis, which is similar to that present in the right upper and lower limbs (*vide infra*).

There was no evidence of paresis in the left limbs, but all movements were performed more slowly than in the normal person owing to the condition of Parkinsonian rigidity.

The muscular power at the right shoulder and elbow joints was only slightly less than that at the corresponding joints in the left arm, but voluntary movements were performed slightly less quickly than in the opposite limb. In the distal muscles of the right arm power was equally good, but the execution of voluntary movements of the wrist and hand was much hampered by the marked increase of tonus which followed the performance of active movements.

The following description may illustrate the disturbance which existed in the performance of voluntary movements in the right hand.

The patient was asked to open the hand from a resting position of moderate flexion of the wrist and fingers. After a delay of two to three seconds the fingers slowly became extended, first at the metacarpo-phalangeal joints and then at the interphalangeal joints; the thumb became extended and abducted. The hand now passed into a condition of involuntary extensor rigidity (see fig. 1), which lasted ten to fifteen seconds. The fingers then slowly flexed at the terminal and interphalangeal joints, but the extensor rigidity of the metacarpo-phalangeal joints still remained marked. Thereafter this in its turn

FIG. 1.—Photograph of right hand showing tonic extensor rigidity.

FIG. 2.—Tonic flexor rigidity of the right hand.

slowly disappeared and the fingers and hand quickly resumed a flexed posture. This was different, however, from the initial resting posture of flexion, because the hand and fingers were now in a condition of flexor rigidity (see fig. 2); this suddenly diminished at the end of ten to fifteen seconds. It must be emphasized that the extensor rigidity and the subsequent movement of flexion were entirely involuntary.

Sometimes, however, instead of the fingers extending at once when the patient attempted to open the hand from the flexed position, they did so only at the metacarpo-phalangeal joints, marked flexor rigidity occurring at the interphalangeal joints. In order to overcome this intense flexor rigidity of the fingers, the patient voluntarily flexed the fingers at the metacarpo-phalangeal joints and at the same time slightly flexed the wrist. This movement was

usually followed by comparatively rapid extension of the fingers and hand. Extensor rigidity now occurred as before.

Two further manœuvres were adopted at times by the patient to open her hand, the necessity for them only occurring when there was a state of rigidity of the flexors of the wrist and fingers. This state of flexor rigidity will be considered later, but at this point it may be mentioned that it always followed active movements or passive movements of large range of the wrist and fingers, or voluntary movements of the right arm.

The patient was asked to grasp the observer's hand tightly; this was carried out promptly. She was then ordered to relax her grip; at the end of ten seconds she partially pronated the forearm, but no relaxation of the grip followed. Then slowly the forearm returned to its former position midway between pronation and supination and the grip tightened slightly. She then extended the elbow and fully pronated the forearm, whereupon extension of the metacarpo-phalangeal and proximal phalangeal joints followed, but the long flexors of the fingers remained in a condition of tonic contraction. She was unable wholly to relax her grip of the observer's hand. Finally, she supinated the forearm and flexed the wrist, and the terminal phalanges became extended. This test lasted two and a quarter minutes.

At other times, especially if the flexor rigidity at the wrist was marked, the patient sometimes strongly flexed the wrist and elbow joints. This was quickly followed by abduction and internal rotation at the shoulder-joint, so that the dorsum of the hand came in contact with the chest wall in the region of the right axilla. She now pronated the forearm and the fingers extended. Extension at the elbow now occurred with full pronation of the forearm, the extensor rigidity of the fingers persisting for about a quarter of a minute. This last posture, namely, extension at the elbow, pronation of the forearm and extensor rigidity in the hand, was quite involuntary.

The hand was more easily closed than opened. If with the hand in extensor rigidity as at the end of a movement of voluntary extension, the patient was asked to make a fist, this order was carried out comparatively quickly. The fingers were first flexed at the terminal phalangeal, then at the interphalangeal, and lastly at the metacarpo-phalangeal joints. Accompanying this last movement or just preceding it, the thumb, previously abducted and extended, became adducted and slightly flexed at all joints. The hand, as a whole, now passed into a condition of flexor rigidity (fig. 2). This condition lasted for some seconds (post-inhibitory exaltation in antagonists).

From a consideration of these observations on the muscular power and performance of voluntary movements in the right upper limb, the following deductions may be made: (1) The loss of voluntary power was exceedingly slight; (2) the execution of voluntary movements with the right hand was difficult, not on account of a paresis but owing to a grave disturbance in the reciprocal innervation of opposing groups of muscles, i.e., when the hand was voluntarily opened the flexors, instead of being reciprocally inhibited, tended to show a further increment of tone. The ease with which the patient was able

to open the hand depended on the previously existing condition of tonus in the flexors of the wrist and fingers; (3) the resulting rigidity affected both flexor and extensor group of muscles, but it appeared more frequently in the flexor group; (4) post-inhibitory exaltation in the antagonists, as described by Sherrington [9], was exemplified in both extensors and flexors.

Voluntary movements at the right hip and knee joints were carried out quite promptly and showed very little, if any, diminution in power. Dorsal and plantar flexion, and inversion and eversion of the foot, were relatively less powerful than the movements of the proximal joints.

Posture and Resting Tonus.

The condition of resting tonus was estimated by passive movements of small range of the limb under examination, the patient being instructed to relax as much as possible,

Tone was moderately increased in all the neck muscles, but predominated in the flexors of the head on the chest. The usual posture of the head in the recumbent or erect position was one of moderate flexion forwards with slight rotation of the chin to the right, the occiput tending to approach the left shoulder. The left sterno-cleido-mastoid was always more prominent than the right.

Resting tonus was moderately increased in all muscle groups of the left upper and lower limbs, and the hypertonus showed all the characteristics of that existing in the Parkinsonian syndrome, i.e., cog-wheel phenomenon, &c. The posture was one of slightly increased flexion at the elbow and partial loss of the normal flexion of the fingers, but the characteristic flexed posture of the arm as seen in Parkinsonism was scarcely present (figs. 7 and 8).

The posture of the right upper limb at rest in the recumbent position was usually as follows: The arm was internally rotated and adducted at the shoulder-joint. The elbow was held in varying degrees of flexion or extension, no constant position at this joint being observed. The forearm was usually in a position midway between pronation and supination; the wrist was slightly flexed, as were all the digits, flexion being more marked in the ring and middle fingers and least in the index finger. The thumb was flexed at the metacarpo-phalangeal and terminal phalangeal joints, and it lay at right angles across the first phalanx of the index finger. This posture of the thumb was probably in part due to a subluxation which existed in the metacarpo-phalangeal joint.

Passive movements of small range showed that the resting tonus in the right upper limb was much less in degree and had none of the characters of that existing in the left upper limb. At the shoulder and elbow joints there was a very slight but appreciable increase in muscle tonus; this was relatively greater in the adductors and internal rotators at the shoulder-joint than in their antagonists. At the elbow-joint a similar minimal increase of resting tonus was present, which seemed about equally distributed to the biceps and triceps; the same equality of tonus was found in the supinators and pronators of the forearm.

At the periphery of the limb, however, a definite increase in the resting tonus was present, but the exact amount was difficult to estimate as passive movements, except through a small angle, provoked reflex tonic contraction in one or other group of muscles and tended to fix the hand or fingers in the particular posture in which they had been placed.

Passive extension and flexion of the wrist from the usual resting position of slight flexion revealed a moderate degree of hypertonus, but such movements could at times be carried out nearly as easily as at the elbow-joint. Passive movements of the fingers showed that there was about the same increase in tone as at the wrist. This increment in tone was greater in the flexors than the extensors.

It must be emphasized that the resting tonus at the shoulder and elbow joints was only slightly increased above the normal, and that even at the periphery of the limb the hypertonus was relatively moderate in amount.

In the recumbent position the usual posture of the right lower limb was as follows: Moderate external rotation at the hip-joint, extension at the knee and pointing down of the foot. At times the foot was inverted and at other times everted. The hallux showed varying degrees of dorsiflexion.

In the left lower leg, as previously stated, there was a condition of general hypertonus, typical of a moderate degree of Parkinsonism. In the right lower limb the resting tonus was much less in degree. As at the right shoulder-joint, there was at the hip-joint a minimal increase in tone, predominating slightly in the flexors and external rotators. At the knee-joint tone was slightly increased, especially in the quadriceps cruris. At the ankle-joint tone predominated in the post-tibial group of muscles. The extensor longus hallucis showed a constant increment of tone which, however, varied in amount.

The Disturbance in Tonus in the Right Upper and Lower Limbs resulting from Active and Passive Movements.

That a marked alteration in muscle tonus existed in the right upper limb has already been shown in the description of active movements involving the right hand. The various alterations in tone resulting from passive movements of larger range will now be considered.

In discussing the question of resting tonus in the right upper limb, it was stated that passive movements of flexion and extension revealed a moderate degree of hypertonus. If, however, such movements were carried out at all roughly or quickly, or through a large angle, then a condition of markedly increased tonus in one or other group of muscles at the wrist resulted, producing a fixation of the wrist into whatever position it had been placed by the observer. In other words, the muscles showed a marked increase of *plasticity*. The same phenomenon was observed at the elbow and shoulder joints of the right upper limb and also in the right lower limb. In the right hand itself other factors modified this reaction, as will be seen shortly.

In the following tests the patient was instructed to relax the limbs as much

as possible, and it was further impressed upon her that she must make no voluntary movement of any kind in the limb under examination:—

(1) After several passive movements of flexion and extension at the wrist had been made, on further extension of the wrist (not the fingers) the following occurred without any further intervention on the part of the observer.

The fingers slowly extended in a similar fashion to that which occurred during active opening of the hand (*vide supra*). The hand now passed into extensor rigidity, which lasted ten to fifteen seconds. The forearm then became pronated, but before this was fully developed more or less rapid flexion of the fingers into the palm and flexion of the wrist occurred. Flexor rigidity was now marked and persisted for ten to twenty seconds. No appreciable alteration in the position of the elbow, which was one of moderate flexion, was observed except during the stage of pronation, when the arm became slightly extended at the elbow-joint.

(2) If passive movements of the wrist were carried out briskly or roughly, a movement of flexion, succeeding one of extension, resulted always in a condition of flexor rigidity of the wrist and fingers (see fig. 2).

(3) When the hand was at rest in a position of flexion, passive movements of extension of any of the fingers resulted in a slow return to flexion, but such a passive movement tended to produce flexor rigidity at the wrist and in the remaining fingers. If, however, more than two fingers were passively extended, the remaining fingers and hand involuntarily assumed the extended position. Extensor rigidity now occurred. If before this had passed off a finger was passively flexed, it at once extended again, and the extensor rigidity in the hand became reinforced. If, however, more than one or two fingers were passively flexed, it was frequently observed that the extensor rigidity at the interphalangeal joints was replaced by a flexor rigidity, extensor rigidity being maintained at the metacarpo-phalangeal joints (this posture has already been described as occurring at times during an active movement of flexion of the hand from an extended position). Thereupon, gradually the hand returned to the flexed position, and flexor rigidity supervened. During these involuntary movements the slightly flexed position of the elbow altered little. To palpation there was no evidence of any appreciable additional increment of tone in the muscles acting on the elbow-joint.

From the above description it is evident that a marked degree of hypertonus in the wrist and fingers resulted from passive movements quickly or roughly performed. This hypertonus could develop, at different times, in the flexors and the extensors—although a flexor rigidity was much more frequently observed. Further, the phenomenon of post-inhibitory exaltation in the antagonists appeared, not only as a result of active movements of the hand, but also as a result of passive movements.

The increase in plastic tonus was also well seen in those muscles which act on the shoulder and elbow joints. The following tests illustrate the tendency for maintenance of any posture into which the limb was put, and also the presence of the *shortening* and *lengthening reactions* which Sherrington [11]

has described as being the most characteristic feature of plastic or postural tonus.

Passive movements at the right elbow-joint were made with the patient in the recumbent position, the left hand of the observer supporting the upper arm. The initial position of rest was: slight abduction at the shoulder, elbow midway between flexion and extension, flexion of the wrist, and flexion of the fingers into the palm.

(1) A passive movement of slight flexion was made and the observer's right hand withdrawn. The forearm fell away slightly, but not to its former level. Two or three similar flexion movements through a small range, performed at short intervals, resulted in less and less falling away of the forearm. After the fourth or so of such flexor movements, the forearm was involuntarily held in the position into which it had been placed ("shortening" reaction in biceps). This posture was maintained for two to three seconds, and was then followed by slow progressive involuntary flexion of the forearm upon the upper arm until full flexion at the elbow resulted ("progressive shortening reaction" in the biceps). During this flexion movement palpation of the biceps showed a steadily increasing increment of tone.

Variations in the result just described were found which depended on the initial posture at the elbow-joint. If a short time prior to such a test as the last, the arm was flexed to a right angle or more, on further passive flexion of the elbow no falling away of the elbow was observed, and after one such movement of flexion the arm became progressively flexed as described above.

If, however, the initial resting posture was one of extension at the elbow, a single passive movement of slight flexion was usually followed by an immediate return to the fully extended position ("shortening" reaction in triceps). If further flexion movements were made, however, the forearm did not return to full extension, but tended to remain in the position imposed upon it ("lengthening" reaction in the triceps).

It is evident from the above description that "shortening" and "lengthening" reactions could be elicited in the biceps and triceps.

(2) A "shortening" reaction was also easily obtained in the deltoid. With the patient in the recumbent position, the right arm, extended at the elbow, was passively abducted to a right angle with the trunk, so that none of the arm touched the bed. The observer's hand was now withdrawn. The arm remained approximately in this position, involuntarily held by the tonic contraction of the deltoid. If, however, the arm, abducted as before, was now flexed at the elbow-joint instead of being extended, the arm at once fell away and resumed its original position. In the former case the arm did not remain in the abducted position for more than three to five seconds, but gradually and involuntarily extended at the shoulder-joint, until it had reached a position above the head in line with the trunk (see fig. 3). In this position the elbow was fully extended and the forearm pronated. The hand was in a condition of tonic flexor rigidity. Once this posture was established it was found that passive flexion of the elbow did not tend to alter the condition of tonic contraction in

the shoulder and neck muscles. This posture of full extension of the arm was maintained involuntarily for a considerable length of time (half an hour in one test) without the slightest symptom of fatigue.

Another method of eliciting the "shortening" reaction in the deltoid and shoulder muscles was by suddenly throwing the patient's arm up into the air. After two or three such movements the arm did not fall but remained tonically held in mid-air. This was rapidly followed by progressive extension at the shoulder-joint as described above,

The condition of resting tonus in the right lower limb has already been

FIG. 3.—"Shortening reaction" in the right deltoid and shoulder muscles (see text).

described; it has been shown that as in the right upper limb there was only a slight increase above the normal. A condition of increased plastic tonus, similar in all respects to that existing in the right upper limb, was also present in the musculature of the right lower limb.

(1) If from the resting posture of extension at the knee-joint the thigh was passively lifted from the bed by means of the observer's hand placed under it, the leg below the knee instead of flexing became fully extended and remained in this position for a few seconds, before slowly returning to the level of the bed. This phenomenon was plainly due to a "shortening reaction" in the quadriceps excited by the weight of the limb.

(2) If, when the leg was tonically extended at the knee as in the previous test, passive slow flexion at the knee was carried out and the observer's hand withdrawn, the leg remained flexed at the knee and at the hip-joint ("lengthening reaction" in the quadriceps).

(3) With the limb at rest, extended at the knee and rotated outwards at the hip-joint, a series of passive flexions of small range were made. After each such movement the position of flexion of the knee was involuntarily maintained. On further passive flexion of the knee a point was reached when palpation of the hamstrings showed an increment of tone, approximately equal to that existing in the quadriceps. If now a further passive movement of flexion was made and the observer's hand was then withdrawn, the leg was progressively and involuntarily flexed at the knee-joint. By palpation it was ascertained that the tone in the quadriceps suddenly showed a marked diminution at the moment when the progressive flexion commenced.

(4) If, with the limb in this flexed posture a passive movement of extension at the knee-joint was made, a considerable resistance was encountered, but at the end of each passive extension the limb tended to remain in that position ("lengthening" reaction in hamstrings). On further extension of the leg, a point was reached at which tone suddenly increased in the quadriceps, and for a few seconds tonus seemed to be nearly equally distributed between quadriceps and hamstrings. Thereupon, tonus suddenly diminished in the hamstrings and this was accompanied by progressive and rapid extension of the leg. The quadriceps was now felt to be strongly contracted (post-inhibitory exaltation in antagonists).

(5) The condition of tone at the right ankle was also of considerable interest. The foot at rest was usually slightly inverted. If a passive movement of further inversion was made the foot remained in this position, tonically held by the tibialis posticus. If now the foot was everted a resistance was encountered which suddenly disappeared as the midline of the leg was approached. Small movements of inversion and eversion could be made with the foot in a line with the leg, without exciting any reflex contraction in the evertors or invertors. Indeed, with the foot in this mid-position, passive movements gave to the observer's hand a feeling of complete lack of tone in the musculature at the ankle, such as is present in a limb recently affected by an acute poliomyelitis. A further movement of eversion resulted in reflex tonic contraction of the peroneals, and the foot remained involuntarily in this position.

It is evident from the above description that plastic tonus was well developed in the muscles of the right lower limb, especially in the quadriceps, hamstrings and invertors and evertors of the foot (being entirely absent in the dorsi- and plantar-flexors). The limb when passively moved tended to retain the position into which it had been placed. If an analysis of the results of passive movement at the knee-joint, as described in paragraphs 3 and 4, be made, it will be seen that both "shortening" and "lengthening" reactions were well marked.

As the limb was progressively flexed by a series of short passive move-

ments, at the end of each movement the limb remained in the position to which it had been brought. The quadriceps had accepted each new muscle length imposed upon it without any obvious alteration in tension. Sherrington showed that this was a property of muscle exhibiting postural or plastic tonus [11].

When the knee was flexed to a certain angle the tonus in the quadriceps suddenly disappeared, and at the same time the hamstrings passed into tonic contraction (post-inhibitory exaltation in antagonists). The leg was then further flexed at the knee without any further intervention on the part of the observer. This can be attributed to a progressive "shortening" reaction in the hamstrings, analogous to that present in the biceps and deltoid in the right upper limb. The leg was now held involuntarily in full flexion owing to tonic contraction in the hamstrings. This illustrates the possibility, under certain conditions, of the development of a flexor rigidity at the knee-joint as well as the more usually observed extensor rigidity. This point will be mentioned later in discussing the experimental findings of Bazett and Penfield.

Successive small passive movements of extension resulted in the maintenance of each position in which the limb was placed ("lengthening" reaction in the hamstrings). Finally a point was reached on further extension when the hypertonus was suddenly transferred from the hamstrings to the quadriceps. As the tone increased in the quadriceps there was an accompanying lowering of tone in the hamstrings (reciprocal inhibition of antagonists). The limb now passed into extensor rigidity (post-inhibitory exaltation in the quadriceps).

Reflexes.

The biceps, triceps and supinator jerks were active in both arms, but more so in the right upper limb.

The abdominal reflexes were brisk in all segments and no difference could be detected between the two sides.

The deep reflexes in the lower limbs were exaggerated, especially on the right side. There was no ankle clonus on either side. The right plantar response was definitely extensor in type, and was accompanied by a well-marked flexion withdrawal reflex of the right lower limb. A nocuous stimulus applied anywhere below the knee was capable of producing this reflex. Stimulation above the knee was negative in this respect. On the left side the plantar response was equivocal. No crossed extension reflex could be obtained.

In the upper limbs reflexes were obtained as the result of nocuous stimuli (Riddoch and Buzzard [6]). In the right limb a pin dragged forcibly along the skin produced a reflex movement of abduction and retraction of the limb, with a tendency to flexor rigidity in the hand. Such a response was obtained not only from the flexor aspect of the forearm, but also from the extensor surface, though the resulting displacement of the limb was less in range when the latter was stimulated. The movement at the elbow-joint varied, being sometimes one of flexion and at other times extension. The situation of the stimulus seemed to have no constant effect on the variety of movement at the elbow. In the left upper limb similar, though less marked, reflexes were obtained, but a flexion reflex was more usually observed. Stimulation of the

extensor surface of the forearm produced no reflex movement. No diffusion of the reflex effect was observed, such as was present in the cases of quadriplegia described by Riddoch and Buzzard. It must be emphasized that the stimulus required to produce a reflex movement in the upper limbs in this case had to be of considerable intensity, sufficient to cause pain.

Form of the Knee-jerk and Flexion Reflex in the Right Lower Limb.

A method of graphically recording the knee-jerk was used. Two Marey tambours, to each of which was attached a writing pen, recorded on a horizontal slowly revolving drum. By means of rubber tubing the Marey tambours were connected to two aluminium recording tambours, oval in shape and similar

FIG. 4.—Posture of right leg with patient in a sitting position (patellar hammer in position, prior to eliciting knee-jerk).

to those employed in recording the venous pulse with the Mackenzie-Lewis polygraph. Across the mouth of each tambour was stretched a piece of thin india-rubber sheeting, and placed in the centre of this was a round piece of cardboard about one-sixth inch thick. One recording tambour was applied to the quadriceps and the other to the hamstring muscles, the distance above the knee being in each case about five inches. These were kept in place by a collar of sticking plaster, reinforced by a strip running longitudinally. In this way errors in the tracings due to global alterations in the limbs were to a great extent overcome. The duration of each record was estimated by means of a stop-watch. Tracings were taken with the patient seated in a chair (fig. 4), and they showed clearly the alterations in muscular tonus accompanying the knee-jerk.

(1) If a single tap was applied to the right patellar tendon an active contraction in the quadriceps took place, which was followed by a rapid fall of the leg, but not to its original position. If a second tap quickly succeeded

the first, the relaxation in the quadriceps was immediately checked, and an increase of tone in the qudriceps produced a complete extension of the leg at the knee-joint (fig. 5). This was accompanied by reciprocal diminution in tone in the hamstrings. This condition of extensor rigidity was maintained involuntarily for several seconds, the time varying in different tests. Then the tonus in the quadriceps diminished slowly and the leg gradually returned

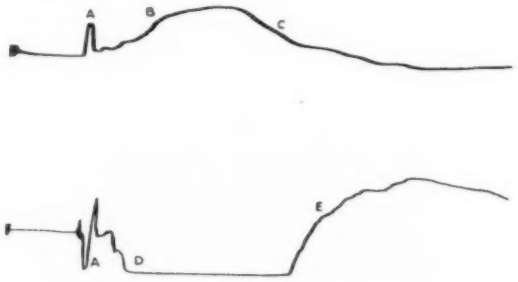

FIG. 5.—Myograph tracing recorded on a slowly moving drum to illustrate the form of the right knee-jerk. Upper tracing from quadriceps, lower from hamstrings. A, patellar tap. B, gradual increase in tone in quadriceps, resulting finally in complete tonic extension. C, slow diminution in tone in quadriceps. D, reciprocal inhibition of tone in hamstrings. E, post-inhibitory exaltation in hamstrings. Duration of record (stop-watch) fifteen seconds (reduced to two-thirds).

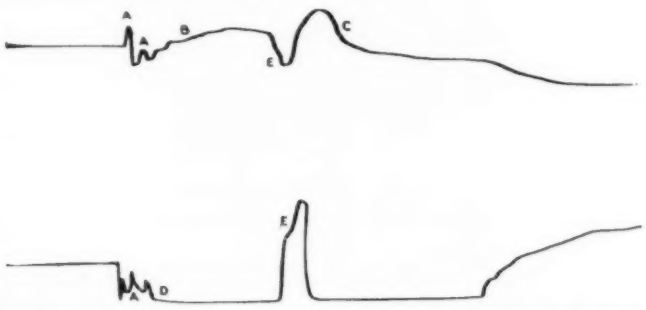

FIG. 6.—Tracings illustrating the breaking through of the extensor rigidity in the right quadriceps by a flexion reflex. A B C D as in fig. 5; E, flexion reflex, resulting in temporary abolition of extensor rigidity, which, however, is almost immediately reinstated owing to post-inhibitory exaltation of tone in quadriceps. Duration of record twenty-one seconds.

to its former position. But instead of remaining in this position it became strongly flexed at the knee-joint (figs. 5 and 6). This secondary increase of tone was due to "post-inhibitory exaltation in antagonists." The duration of the flexor rigidity varied between five and fifteen seconds. The development of the flexor rigidity was comparatively rapid, and it passed off rather more slowly than the extensor rigidity.

These results were constant in a large number of tracings which were recorded.

(2) A condition of extensor rigidity was produced by elicitation of the knee-jerk. A nocuous stimulus was now applied to the sole of the right foot, thereby producing a flexion reflex (fig. 6). This was of short duration and was at once replaced by an extensor rigidity (post-inhibitory exaltation) which, however, persisted for a shorter time than in the first tracing (compare figs. 5 and 6). The subsequent flexor rigidity was as marked as in fig. 5.

These tracings show graphically the existence of "shortening" and "lengthening" reactions, post-inhibitory exaltation in antagonists and reciprocal inhibition of antagonists, in the quadriceps and hamstrings of the right lower limb. These phenomena have already been described clinically earlier in this paper. Further, the second tracing (fig. 6) shows clearly that the extensor rigidity could be broken through by a phasic or kinetic reflex, namely the flexion reflex. This fact is important, as Sherrington [11] has shown that such a result is characteristic of a muscle showing increased plastic or postural tonus.

Variations in the Form of the Flexion Reflex.

With the patient in the recumbent position and the right lower limb in extension, a nocuous stimulus was applied to the sole of the right foot. A well-marked flexion reflex followed. A greater degree of flexion at the knee was obtained from stimulation of the inner half of the sole. The position of the foot, whether one of inversion or eversion, did not seem to modify the resulting displacement of the limb. In place of external rotation of the limb at hip-joint, internal rotation of the limb with inversion of the foot was sometimes observed as a resting posture. If now the outer part of the sole of the foot was stimulated, a moderate flexion reflex was obtained, the foot tending to invert further. However, as a result of stimulation of the inner half of the sole, the resulting movement of the limb was primarily one of external rotation at the hip-joint. If this movement was not complete with the first stimulus, a further stimulus produced an increased degree of external rotation. Finally, towards the end of this movement, a slight flexion reflex took place, the foot usually becoming everted, as well as dorsiflexed.

So far the alterations in posture and tone present when the patient was in the recumbent position have been described. It is now necessary to consider these factors with the patient in the sitting and erect positions.

Posture in sitting position.—The head and upper limbs showed no appreciable alterations in posture from that described as present in the recumbent position. The left leg assumed a natural position. The right thigh was seen to be at a higher level than the left. The right knee was held slightly less flexed than in the case of the left leg, and the right heel was raised from the ground. At times, especially when the patient made a voluntary movement of the trunk, the toes of the right foot became strongly plantar flexed (fig. 4), and the flexors of the hip and knee joints could be felt in tonic contraction.

Erect posture.—When the patient assumed the erect position, certain well-marked and constant alterations in tone and posture in the limbs on the right side resulted.

The patient, seated in a chair with a table on her left, was asked to rise to a standing position. Firstly, she placed her left hand on the table and then she flexed the right leg at the hip-joint to approximately an angle of 45° with the trunk. The leg simultaneously became tonically extended at the knee, and the foot pointed downwards. The flexors of the hip, extensors of the knee and plantar flexors of the foot were felt to be in a condition of tonic rigidity at

FIG 7.—Patient in upright position. Note the decerebrate posture of the right arm and characteristic Parkinsonian smile.

this stage. It must be emphasized that this initial posture seemed quite involuntary, except in so far as the condition was activated by the patient's desire to stand erect. Following this the right leg became flexed at the knee (voluntarily) and the foot became inverted, the toes remaining strongly plantar flexed. The patient then transferred her weight forward and both legs became extended at the knee. This brought the patient into the upright posture. During the first stage the right arm became slightly abducted at the shoulder; as the patient bent forward it became further abducted, extended at the elbow and pronated. When she was finally standing up the arm returned

to the side, but still remained extended and pronated. The hand was in a condition of flexor rigidity throughout.

In the standing position the right leg was held slightly in advance of the left, and the weight tended to be placed more on the left. At times the toes became acutely plantar flexed with arching of the foot. This resulted from every voluntary change in position of the trunk.

Posture in walking.—The patient was able to walk alone, but did so with considerable difficulty, and tended to lose her balance owing to the posture which was involuntarily assumed by her right leg.

FIG. 8.—Photograph illustrating the terminal phase of a step in walking (see text). Note the retraction and abduction of the right upper limb and the extensor rigidity in the right lower limb.

The patient was asked to walk, starting with the left foot. This she did, but it was noted that the right leg did not flex at the knee as she advanced the left leg. She then proceeded to take a step with the right leg. The first movement was one of voluntary flexion at the knee. Thereupon powerful overflexion at the hip-joint with slight inversion occurred, and was accompanied by marked extensor rigidity of the leg. This second phase, except at its commencement, seemed entirely involuntary, and the patient was quite powerless to inhibit the overflexion at the hip-joint and extension of the knee.

The foot in this position was usually eight to twelve inches above the level of the ground. The rigidity then slowly passed off, allowing the leg gradually to return to the ground (fig. 8). During this phase the limb became externally rotated at the hip-joint and the foot, previously inverted, became everted. The toes touched the ground first, and as further relaxation took place the heel was progressively lowered.

When walking, the right upper limb was abducted and retracted at the shoulder-joint and extended at the elbow; the forearm was over-pronated and the right hand rigidly flexed. As the extensor rigidity in the right lower limb passed off, the right arm returned to the side, but maintained the posture described above. The left upper limb during walking became slightly abducted at the shoulder and more flexed at the elbow (fig. 8).

Although these extended postures of the right upper and lower limbs were much more pronounced in the erect position, they were also seen frequently in the recumbent position as a result of any voluntary movement involving the trunk, such as turning over in bed or sitting up. The extended posture of the right upper limb was not so definite under these circumstances, however, as that observed in the upright position.

This description illustrates the striking constancy of a posture of extension accompanied by rigidity in the right upper and lower limbs, which appeared on the assumption of the upright position. This posture was tonic and resembled closely that observed clinically by Wilson, Walshe, Riddoch and Buzzard, and Kraus and Rabiner, and experimentally by Sherrington and by Bazett and Penfield in the decerebrate animal.

Associated Movements.

The following tests were carried out with the patient in the recumbent position. The right upper limb was in a position of rest, namely, semiflexed at elbow-joint, forearm midway between pronation and supination with moderate flexion of the wrist and fingers. The head was in the midline.

(1) Forcible contraction of the left hand resulted in flexor rigidity of the right hand, varying in degree, but no appreciable alteration in tonus in right biceps, triceps, or shoulder muscles. No change in tone in the right leg.

(2) Flexion of the left elbow-joint against resistance produced slight flexion of the right elbow and flexor rigidity of the right hand. The right pectorals contracted.

(3) Extension of the left elbow-joint was accompanied by extension of the right elbow, slight increase of the flexion of the right wrist, adduction and internal rotation of the right shoulder, but no apparent pronation of the right forearm. The extension of the right elbow was maintained involuntarily after voluntary movement of the left arm had ceased, and was uninfluenced by a quickly succeeding voluntary flexion of the left elbow against resistance.

(4) Adduction and abduction of the left shoulder against resistance produced extensor rigidity of right arm, as in previous test.

During none of these tests was any perceptible alteration in tone in the right lower limb observed.

Magnus and De Kleijn reflexes.—No appreciable variation in the above findings was observed as a result of passive alterations in the position of the head, either in the recumbent or erect postures. Considerable attention was given to this point in the light of the clinical observations of Simons [12] and Walshe [18].

The Effect of Sleep on Muscular Tonus.

An opportunity was afforded on one occasion when the patient fell asleep of observing the effect of the removal of higher cerebral control on the condition of muscle tonus.

The right hand, being in the resting posture of flexion, was passively extended, though not completely so. Thereupon the hand passed into well marked extensor rigidity, which was maintained for ten to fifteen seconds.

The right arm was passively extended at the elbow and abducted. This position was retained and there followed a progressive rising of the arm, till it became fully extended at the shoulder, as previously described (fig. 3). This posture was maintained.

On the patient awaking she was asked if she was aware that her right arm had been moved, and she replied that she had been asleep and remembered nothing.

These observations are of importance as proving conclusively that the various changes in tone and posture observed in the musculature of the right upper limb as a result of passive movement occurred without any voluntary intervention on the part of the patient.

Tremor.—No tremor either of the head, left upper and lower limbs or right lower limb was ever observed. In the right upper limb a tremor was at times evident which had some special features. If the patient stretched out her right arm in front of her, or made a voluntary movement of this limb with the elbow in a position of extension, a coarse pendular tremor was occasionally observed. The origin of this tremor seemed to lie in the shoulder muscles. The resulting displacement of the limb was in an antero-posterior direction. The rate was slow, being three to four per second. The tremor was only apparent at the commencement of the voluntary movement and disappeared after a few seconds. The range of movement, at first considerable, became progressively less. The tremor was also observed at times when the right arm was passively thrown up into the air; it never followed a slow passive movement.

This tremor seems analogous to that described by Riddoch and Buzzard, as occurring in some of their cases of quadriplegia. They suggest that such a tremor can be explained by the phenomenon of "double reciprocal innervation" (Sherrington) and that it results from the action of two equal but antagonistic forces acting alternately, the stimulus starting the biphasic movement being the weight of the limb. This explanation would seem to apply perfectly to the tremor in the present case.

Negative Findings.

There were no spontaneous involuntary movements in the right upper and lower limbs. All forms of sensation were normal on the trunk and in the limbs. The special senses were normal. An investigation of the cerebellar functions showed that these were normal on both sides. Sphincter control was normal.

Occasional slight rises in temperature were observed during her residence in hospital. Physical examination never showed any cause for these, except on the occasion already referred to when the pyrexia was accompanied by diplopia.

In view of the experimental findings of Bazett and Penfield, as regards the loss of temperature control in decerebrated cats, observations were made of the relative temperature on the two sides of the body. No difference was ever detected. The patient was never aware of any subjective difference in the temperature on the two sides. No abnormal vasomotor phenomena were noted.

Résumé of Case.

A young female, aged 21 years, had a typical attack of epidemic encephalitis in April, 1919, complicated by a slight right hemiplegia which appeared on the fourth day of the illness. Subsequently a condition of Parkinsonism appeared, but remained limited to the head and limbs on the left side. The right upper and lower limbs showed no evidence of this affection, but on this side there existed signs of a pyramidal lesion with a definite extensor plantar response. A condition of postural or plastic tonus was present to a marked degree in the musculature of the right limbs, and the resulting tonic rigidity which followed voluntary movements of these limbs greatly hampered the use of these parts. In the erect position, a posture approximating to that observed in the decerebrated animal was present in the right upper and lower limbs.

Discussion.

There can be no question that the fundamental basis of the clinical condition in this case was an alteration in muscular tonus.

There are several clinical facts which I believe should be emphasized at this point: (1) The relatively slight increase of resting tonus in the right upper and lower limbs, and the consequent absence of continuous contractions producing postural deformities. (2) The almost complete conservation of voluntary muscular power in these limbs. (3) Passive movements of wide range or voluntary movements of the right upper and lower limbs resulted in an increase in tone which had all the characteristics of plastic tonus, as defined by Sherrington. (4) The

presence of both flexor and extensor rigidity in these limbs, the latter especially being prominent when the patient assumed the erect posture.

Posture.—The posture, especially when the patient was erect, approximated closely to that observed clinically in human decerebrate conditions and in experimental animals. An attempt will be made to correlate the posture in this case with that existing in the decerebrated animal.

In the recumbent position the posture of the right upper limb was not constant, especially at the shoulder and elbow joints. The hand at rest was in a position of slight flexion of the wrist with the fingers flexed into the palm. Voluntary movements of the right hand resulted in either an extensor or flexor rigidity, the type depending on whether the original voluntary movement was one of extension or flexion. A similar rigidity of the wrist and fingers was observed as a result of passive movements of the hand when these were large in range or roughly performed. At times an extensor rigidity at the elbow-joint, with pronation of the forearm and flexor rigidity of the hand, was observed in the recumbent position, usually as a result of voluntary movements of the trunk.

In the right lower limb the resting posture was one of extension of the knee-joint; the foot tended to point downwards and the hallux was dorsiflexed. In the recumbent position extensor rigidity occurred constantly in this limb as a result of movements involving the trunk, as in turning in bed; more rarely a condition of flexor rigidity at the knee-joint was observed. In the erect position the posture of the limbs was much more stereotyped, namely, extension at the elbow-joint and pronation of the forearm and flexion of the fingers into the palm. While walking abduction and retraction at the right shoulder-joint, in addition to extension at the elbow-joint and pronation of the forearm, was constantly observed. At the same time the right lower limb showed well marked extensor rigidity at the knee-joint, with hyperflexion at the hip-joint.

It is clear that the hypertonus which was present in the erect posture predominated in the extensor muscles of the right upper and lower limbs. In the recumbent position extensor rigidity was much less frequently observed and only resulted from movements of the trunk.

The posture while the patient stood erect seems similar to that observed by Sherrington in the decerebrated animal. He showed that

the rigidity was distributed to those muscles which were employed in the maintenance of the erect posture.

The rigidity in the present case was not confined to the extensor group of muscles; it has been shown that a flexor rigidity of the wrist and fingers was the more constant finding in the right upper limb. Flexor rigidity at the knee-joint was at times also observed. Such a condition of flexor rigidity was occasionally noted by Sherrington; Thiele [14] and Graham Brown [2] observed in the decerebrate monkey flexion of one fore-limb with simultaneous extension of the other, as a result of unipolar stimulation of the red nucleus.

More recently Bazett and Penfield [1], working on chronic as well as acute decerebrated preparations of the cat, found that an extensor rigidity might alternate with one of flexion, and that the more chronic the preparation the more tendency there was for a flexed position to appear. "In the chronic preparations they (i.e., rigid flexed positions) are a comparatively common occurrence, and indeed some degree of flexion is usually found in one or more of the limbs after the first five to ten days, and, though it may alternate with extension, yet flexion may sometimes be the more constantly maintained posture." In their conclusions they state: "The term decerebrate rigidity is generally taken to mean extensor rigidity. But in completely decerebrated specimens another type of rigidity sometimes appears, tonic contraction of the flexor aspect of the limbs. . . . After semi-decerebration this phenomena appeared much more frequently, alternating with extensor rigidity as though complementary to it. It would be more accurate, therefore, to speak of extensor and flexor rigidity as two types of decerebrate rigidity."

There seems to be a striking analogy between the findings of Bazett and Penfield in the chronic decerebrate cat and the condition of rigidity which was found in the present case in the right upper and lower limbs.

Before leaving the question of posture, mention must be made of the position of the head. In the recumbent and erect postures there was a slight tendency to rotation of the head, so that the chin was turned to the right and the occiput was slightly approximated to the left shoulder (see fig. 1). Bazett and Penfield [1] in their unilateral decerebrate preparations noted that the head adopted a so-called "cerebellar attitude," but instead of the head being retracted to the side of the lesion as in cerebellar affections, it was constantly held away from the lesion.

Tone.—The most striking feature of this case is the difference in

tonus which existed when the right upper and lower limbs were at rest and when they were moved either voluntarily or passively. There was no continuous rigidity such as that described by Sherrington in his acute decerebrated animals and clinically in cases described by Wilson and Walshe. Bazett and Penfield [1], however, found in their chronic preparations that at times the limbs became flaccid, but that when the animals were handled the limbs again became rigid. A similar condition has been described in the present case.

As regards the disturbances in tone, this case is similar in most respects to the cases of quadriplegia which formed the basis of an exhaustive study by Riddoch and Buzzard, in which they have applied clinically the criteria of postural or plastic tonus, as originally described by Sherrington.

The distribution of the plastic tonus in this case is of interest. As has already been shown, the patient was at times unable to open her eyes, and it has been previously suggested that this was due to an alteration in tonus similar to that found in the limbs on the right side. The remaining facial and neck muscles showed no evidence of plastic tonus. On the contrary these, with in addition the left upper and lower limbs, were the seat of a hypertonus characteristic in all respects of that found in the Parkinsonian syndrome.

In the right upper limb at rest there was a minimal increase in tone at the shoulder and elbow joints, but at the wrist-joint and in the fingers this was more marked. The hypertonus was much accentuated by active movements, or passive movements roughly performed. In the right lower limb a similar difference in the resting tonus and that resulting from active or passive movements was observed.

The adjective "plastic" has been used in describing this type of muscular tonus. Sherrington [10] used this term to describe the altered condition of tone which he found in the muscle of the decerebrate cat. He later used synonymously the word "postural."

In describing "lengthening" and "shortening" reactions, he writes [10]: "The posturally acting muscle has taken up a new postural length and is now shorter than before, but exhibits the same tension as its previous length," and a few lines further on: "The limb brought by active or passive movements into a new posture when released remains in that new posture. . . . The postural reflex contraction is plastic in this sense, hence the term plastic tonus has been applied to it."

Sherrington [10] has described the various attributes of plastic

tonus as seen in the musculature of the decerebrated animal. The most characteristic of these were present in the present case.

(1) *"Shortening" and "lengthening" reactions* were well exemplified. The following observation, amongst others, illustrates the "lengthening" reaction as observed in the right quadriceps muscle. The right lower limb raised passively from the bed became tonically extended at the knee, and would remain in this position unsupported for several seconds. If now the knee was passively flexed the leg remained flexed at this angle. In other words, the quadriceps had adapted itself to the greater length passively imposed upon it without any obvious alteration in tension. Similar lengthening reactions were observed and have been described in the hamstrings of the right lower limb, in the triceps and in both flexors and extensors of the wrist of the right limb.

A "shortening" reaction was clearly observed in the right quadriceps. The first phase of the above test for "lengthening" reaction was due to "shortening" reaction in the quadriceps excited by the weight of the lower leg. A further example of a "shortening" reaction in the same muscle has already been mentioned in describing the knee-jerk. After a single tap on the patellar tendon the lower leg did not return to its former position but remained slightly less flexed at the knee-joint. If a further succession of two or three taps were applied, after each it was noted that the leg tended to become less and less flexed. Finally, the quadriceps became progressively shorter, resulting in a fully extended position of the leg (fig. 5). Similar "shortening" reactions have been described in connection with most of the musculature in the right upper and lower limbs. Progressive "shortening" reactions [16] were also present in a remarkable degree in certain muscle groups. In the case of the quadriceps, at times only a single tap on the patellar tendon was sufficient to produce this phenomenon. The leg partially fell away after the tap, but thereupon progressively became more and more extended, so that at the end of two or three seconds the leg had passed into involuntary extensor rigidity. Progressive "shortening" reactions were also observed in the biceps in the right upper limb, and in the right hamstrings. The most striking example of this phenomenon was seen in the right deltoid and shoulder muscles. When the right arm, extended at the elbow, was passively abducted from the side in a somewhat abrupt manner, the arm remained unsupported in this position for two or three seconds. The arm then progressively rose higher and higher until it reached a point above the head in a line with the body. There the arm would remain for many minutes, involuntarily held

by the tonic contraction of the neck and shoulder muscles. This test was also carried out when the patient was asleep and showed no variation from the above description.

This phenomenon seems similar in many respects to that familiar experiment, pointed out by Wertheim Salomonson [7], in which normally, if the arm, held in a position alongside the body, be pressed voluntarily against a wall for a minute or so, on withdrawing from the wall the arm progressively and involuntarily becomes abducted to a right angle or more with the trunk. He noted that this reaction was most marked in the deltoid and extensors of the hand in normal persons. A progressive "shortening" reaction in the deltoid and shoulder muscles excited by the weight of the limb would seem to be the most plausible explanation in the present case of this phenomenon.

(2) "On withdrawal of the stimulus producing the flexion reflex, not merely does the flexion lapse, but it is followed by active extension. This rebound extension appears due to a post-inhibitory exaltation of activity in the previously inhibited extensor centre." In these words Sherrington [10] has described the phenomenon of post-inhibitory exaltation in the antagonists.

Graphic tracings of the knee-jerk and flexion reflex (figs. 5 and 6) show the presence of this reaction, not only in the quadriceps but also in the hamstring muscles in the right lower limb.

(3) *Lack of muscular fatigue* is another prominent feature of increased plastic tonus, and this is well exemplified in the present case. The right arm extended involuntarily above the head remained in this position for half an hour in one test; at the end of that time the patient did not complain of the least fatigue in the limb, and was at once able to carry out voluntary movements involving the right shoulder-muscles against resistance, without any appreciable diminution in the amount of muscular force.

(4) Sherrington showed that in muscles exhibiting well marked plastic tonus, a tonic reflex is inhibited by a movement reflex which originates in an antagonistic group of muscles. Fig. 9 clearly shows this point. As a result of two successive taps on the patellar tendon the quadriceps progressively shortened owing to tonic contraction. Whilst the leg was still in the fully extended position, a nocuous stimulus was applied to the sole of the foot, thereby producing a flexion reflex. In other words the tonic contraction of the quadriceps was overcome by the kinetic reflex involving the hamstrings.

(5) Sherringon also pointed to the difficulty of obtaining by arti-

ficial means, such as electrical stimulation, a reflex contraction at all closely resembling the postural contraction produced by the natural stimuli, whatever these may be. In the present case, the musculature of the right upper and lower limbs responded in a normal manner to both faradic and galvanic stimulation, and this failed to produce the changes in tonus resulting from active or passive movements of these limbs.

Site of the Lesion.

The localization of the morbid process in this case is of importance, but owing to our imperfect knowledge of the anatomical basis of clinical conditions similar to the present one, only an approximate guess of the situation of the lesion can be made. This question can be approached from two different standpoints: (1) the site of the lesion in the Parkinsonian syndrome, (2) the anatomical basis of experimental decerebration.

(1) *The site of the lesion in the Parkinsonian syndrome.*—The present writer in a previous communcation [5] has shown that the Parkinsonian rigidity and posture following epidemic encephalitis may be attributed to a destruction of the cells of the substantia nigra. This evidence would point, in the present case, to a lesion in the midbrain, which would account for the Parkinsonian rigidity affecting the face and neck and the left upper and lower limbs. At present there is little available evidence to show whether destruction of the cells of the substantia nigra on one side is followed by a unilateral or crossed Parkinsonism. Trétiakoff [15], in his thesis, mentions one case to which considerable importance has been attached, in which a lesion of the substantia nigra of one side was found in a case of unilateral paralysis agitans affecting the limbs on the opposite side. This case was not a sequel of epidemic encephalitis and further no mention is made of any examination of the basal ganglia. Therefore, I think that, at least for the present, the evidence afforded by this single case should be disregarded.

An opportunity has occurred of observing and following a number of cases of unilateral Parkinsonism following epidemic encephalitis. In these cases the affection remained unilateral for periods varying from one to two years, but sooner or later in the great majority of the cases the limbs on the opposite side became affected. In the present case three and a half years have elapsed since the appearance of the unilateral Parkinsonism, and there is still no evidence of a similar involvement of the right upper and lower limbs.

The absence of Parkinsonian signs on the right side could be explained in one of the following ways: (*a*) It might be assumed that the affection of the substantia nigra was unilateral. But it has already been pointed out that a Parkinsonism which remains unilateral is a rarity. In the more usual cases in which the symptoms become bilateral, it is reasonable to suppose that the encephalitic process has now affected the substantia nigra on both sides. In the present case, therefore, it is probable that the affection of the substantia nigra is bilateral. (*b*) The absence of a Parkinsonian rigidity on the right side could be explained by the effect of a secondary lesion at a lower level than the substantia nigra, affecting some structure in such a way as to have prevented the appearance of the Parkinsonian condition, and at the same time, as a release phenomenon, has permitted the development of the altered condition of tonus in the right upper and lower limbs.

(2) *The anatomical basis of experimental decerebration.*—The plastic tonus and the frequently observed decerebrate posture in the right upper and lower limbs are so similar to those described by Sherrington in the decerebrated animal that it seems reasonable to presume a second lesion in a similar location as that in his experiments.

Sherrington [8], in 1898, produced a decerebrated condition in animals by coronal transection of the brain-stem between the anterior and posterior colliculi. He found that a transection as far caudal as the pons resulted in the same condition. When the transection reached the plane of the calamus scriptorius, rigidity disappeared.

Magnus [4] found that the transection must be as low as the anterior part of the midbrain, and that the rigidity persisted with a lesion as far caudal as the entry of the eighth cranial nerve, but that when the calamus scriptorius was reached the rigidity disappeared.

Extirpation of the cerebellum, as shown by Sherrington, Thiele, and Magnus, does not alter the decerebrate state.

Bazett and Penfield observed in their experiments on cats that decerebration persisted after destruction of the red nuclei and superior cerebellar peduncles.

Sherrington [8] found in his acute preparations that the resulting rigidity from unilateral decerebration was less constant than in complete section of the midbrain. It was usually present in the ipsilateral limbs, and he noted that its intensity varied considerably. The limbs on the side opposite the lesion showed a degree of flexion in excess of the normal.

Thiele [14] also, in acute preparations, noted ipsilateral rigidity and that, if the section were more anterior, the rigidity tended to become contralateral.

Bazett and Penfield [1] adopted two types of removal in their unilateral preparations: (*a*) "anterior," where the decerebration passed above the inferior colliculus, leaving a varying amount of the superior colliculus intact and most of the midbrain ventrally, the red nucleus not being involved; (*b*) a "posterior" type of removal, where the section passed from behind the inferior colliculus dorsally, to the anterior margin of the pons ventrally. In this type one red nucleus was removed. In the "anterior" preparations these authors found that shortly after the operation extensor rigidity was present on the *same* side as the lesion, but after three days or so the extensor rigidity was no longer observed in the ipsilateral limbs, but was now present in the *contralateral* limbs. This condition remained until death.

In the "posterior" type of removal the results were less constant. In one animal which survived for forty-five days there was considerable variation in the distribution of the rigidity, but on the whole there tended to be tonic extension of the limbs on the contralateral side.

Bazett and Penfield attribute the appearance of an ipsilateral rigidity in the first few days following the operation as due to an irritative effect, and from their observations on more chronic preparations they conclude that unilateral decerebration is followed by rigidity in the contralateral limbs.

The evidence afforded by the experimental findings of Bazett and Penfield, if applied to the present case, would point to a lesion in the *left* side of the brain-stem, in order to account for the condition existing in the limbs on the right side.

Summary.

(1) A clinical description has been given of a case showing unusual sequelæ of epidemic encephalitis, namely: (*a*) left unilateral Parkinsonism; (*b*) the presence, in the right upper and lower limbs, of well marked plastic tonus and decerebrate postures, associated with signs of a pyramidal tract lesion.

(2) The muscular tonus in the right upper and lower limbs has been shown to possess all the features of increased "plasticity" as originally described by Sherrington in the musculature of the decerebrated animal.

(3) The postures observed at times in the right upper and lower limbs, resembling those found in the decerebrated animal, have been discussed in the light of Sherrington's observations and the more recent ones of Bazett and Penfield.

(4) Some evidence has been advanced to show that this clinical syndrome may be caused by a bilateral affection of the substantia nigra, with a caudal extension of the lesion on one side.

I am much indebted to Dr. Campbell Thomson for permission to publish this case.

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A FORM OF FAMILIAL CEREBRAL DEGENERATION CHIEFLY AFFECTING THE LENTICULAR NUCLEUS.

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THIS paper has been written for the purpose of recording the family history and the microscopical lesions in two cases of what we believe to be a new form of familial cerebral degeneration.

In April, 1922, one of us (D. P.) showed an infant, diagnosed clinically as a case of familial cerebral degeneration, at a meeting of the Royal Society of Medicine (Section for the Study of Disease in Children). Since this time the child has died and a post-mortem examination has been obtained. Meanwhile a brother of this child was born and died, and an autopsy was also obtained. We propose recording these two remarkable cases.

FAMILY HISTORY.

The mother's age was 37 when her last child was born. She appears a fine healthy woman. Her colour is good and she has always been able to do a good day's work. She has had no nervous illnesses. No septic foci can be found on examining her mouth or throat. There is a history that even before she was married at the age of 20 she had a leucorrhœal discharge, and this has persisted throughout her married life up to the present, even during pregnancy. She refuses to allow an examination by a gynæcological expert, hence no notes can be given as to the nature of the discharge or its bacteriology. It is significant, however, that she has not consulted a doctor about it, and only on one occasion has she had even a hint of sepsis after childbirth. Her Wassermann reaction is negative. She states that during the time she is pregnant she is extremely miserable, and has always been so, although physically she seems quite fit. Her appetite was not in any way abnormal during pregnancy and she ate what the family did. She has never had more than slight vomiting while pregnant, and has never been jaundiced. Her mental outlook is peculiar and unbalanced, in marked contrast to her sane view of life when not pregnant. Her family history fails to show anything abnormal to account for the cases to be described. The father at the time of the birth of the last child was aged 49.

He is a gardener and a strong healthy man who does a heavy day's work each day. He has had no illness beyond rheumatism at times. There is a family history of rheumatism but nothing else. His brothers' families are quite normal. The Wassermann reaction is negative in his case too.

The mother has had twelve pregnancies which have resulted as below :—

First : Male born May 24, 1906 ; died aged 4 months.
Second : Male born September 24, 1907 ; died aged 9 months.
Third : Male born November 9, 1908 ; now alive and well, aged 15 years.
Fourth : Female born March 22, 1910 ; now alive and well, aged 13 years.
Fifth : Male born July 18, 1911 ; died aged 6 months.
Sixth : Male born November 11, 1912 ; died aged 2 years.
Seventh : Female born February 28, 1914 ; premature, died aged 6 days.
Eighth : Male born June 21, 1915 ; died aged 6 months.
Ninth : Male born September 17, 1917 ; died aged 4 months.
Tenth : Male born October 8, 1919 ; died aged 5 months.
Eleventh : Male born October 18, 1921 ; died aged 7 months.
Twelfth : Male born February 27, 1923 ; died aged 3 days.

General Remarks on the first ten Children.

Beyond the fact that the mother was low spirited and nervous during the ante-natal period on all occasions, there was very little else abnormal to note. How far this low-spirited condition was due to the large mortality of her offspring it is impossible to say, but she states that she grew to dread the birth of a child as she knew that she was sure to lose it. The birth of the two children now living was in no way different from that of those that died, and she felt no difference while carrying them. Her statement at times varied on these points, but the truth is probably as stated. The labours were all easy and at no time were instruments used. Usually labour lasted six or seven hours, but on one occasion one of the children was born while she was washing clothes.

All the children except the seventh, which was one month premature, were full term, and they appeared normal at birth and took their food well. They all, however, became slightly jaundiced shortly after birth, but this soon passed off. At no time was the placenta noted to be abnormal in any way to the naked eye, but unfortunately no histological or bacteriological examination was made.

About the third month after birth, except in the cases of the third and fourth children who are alive and well, the children became apathetic and lost interest in their surroundings. The mother thinks they did take notice as they ought to at first, but one cannot but doubt that they were ever normal ; probably their apathy became more and more noticeable as they grew older and more feeble physically. Convulsions occurred in all the children, even in those children who are alive and apparently perfectly healthy to-day. The children which died were thought to be blind. In nearly every case these children were brought to London to one of the large hospitals, where they

were seen by various children's specialists and the same diagnosis was always made—that of "amaurotic family idiocy." No one, however, appears to have seen the cherry red spot in the fundus, although it was looked for repeatedly. A post-mortem examination was performed on the tenth child but nothing abnormal was visible macroscopically.

At first these children took their feeds well but gradually became more and more difficult to feed. They swallowed badly and refused to suck. They never at any time showed symptoms of any gastro-intestinal disturbance. None of them had spastic or flaccid paralysis, and although they were content to lie quietly where placed and could move all their limbs and cry loudly, they could not raise their heads from the pillow.

The history of the sixth child who lived to the age of 2 years deserves special mention. His mother states that he became quite a tall child but he was never able to lift his head. He always appeared quite mentally deficient and in fact was considered an idiot. He could see, however, and would hold objects in his hands. He did not display athetoid movements and lay quietly where placed.

History of Eleventh Child.

Chas. S. was a full-term child. The labour was easy and he appeared quite normal at birth. When between 3 and 4 months old he seemed to fail to notice things and became quiet and apathetic; his mother thought that he could not see. He took his feed progressively worse and latterly had to be spoon fed. He could hear, for he appeared to jump when loud noises were made close to him. His muscles were weak but there was no paralysis, and he could move his limbs. There was never at any time spasticity. He had had no convulsions. He was not able to raise his head from the pillow.

He was first seen by one of us (D. P.) at the Hospital for Sick Children, Great Ormond Street, on April 21, 1922. He was thin and pale, his weight was 11 lb. 12 oz. He had well-marked rickets, the bony changes were demonstrable by X-rays. He was well formed and his heart, lungs, and abdomen appeared to be quite healthy.

He did not appear to be able to see and could not follow a light with his eyes. Repeated examinations of the fundi by several different observers, including the ophthalmologist to the hospital, failed to reveal the cherry red spot or other abnormalities, and the pupils reacted to light. There was a slight external squint which was noted for the first time at this examination.

The child would lie quite apathetically in his mother's arms and would not take the slightest notice of his surroundings. He appeared to be staring ahead into the distance. He was able to move his limbs and could roll his head from side to side. No athetoid movements were observed. He was, if anything, less emotional than a normal child and would allow examination without crying. He did not smile.

The knee-jerks were brisk, but no spasticity was noted and all other reflexes were normal. The child had a very poor cry but the respiratory muscles acted well. So far as was known this child was never feverish.

The child was shown at the Royal Society of Medicine (Children's Section), where the probable diagnosis of amaurotic family idiocy was discussed. Death took place during the last week in April, 1922. A post-mortem examination was obtained which will be discussed later.

The Wassermann reactions in the blood of this child and of his brother and sister were all negative.

History of Twelfth Child.

This infant was born at full term on February 27, 1923. A slight degree of cyanosis was present a few hours after birth, but passed off. A careful examination by one of us (D. P.) revealed nothing abnormal about the child; when seen on the second day his bowels had moved, he was taking the breast and appeared to be quite satisfactory. Suddenly on the third day he had another attack of cyanosis and died. He was never feverish.

A post-mortem examination was also obtained on this child and is to be given in detail later. The placenta in this case was said to be quite normal to the naked eye. No microscopical examination was made.

PATHOLOGICAL EXAMINATIONS.

The pathological examination on the twelfth child will be detailed first as the most striking changes were found in it.

The post-mortem examination was made fourteen hours after death. No yellow discoloration nor evidence of jaundice was present. Macroscopically no abnormality was observed in any of the thoracic or abdominal organs, including the liver. The brain and spinal cord appeared normal except for the lack of differentiation between grey and white matter which is usual in the newly born. The meninges were not thickened and the cerebro-spinal fluid was clear.

Microscopic examination of the spleen, thymus, kidneys and liver revealed no departure from normal. The organs of the central nervous system, however, showed many abnormalities which will be described in detail. Great difficulty was experienced in obtaining firm fixation of the brain.

Basal Ganglia.

When the brain was cut by a horizontal section through the basal ganglia an examination of the cut surface showed that the general configuration of the ganglia and tracts was present. But situated at the anterior and posterior extremities of the lenticular nucleus in close proximity to the internal capsule were small seed-like bodies. On section they did not appear larger than a small apple seed. They were apparently separate from the surrounding tissue and the resemblance to capsulation was striking. A similar small area was observed in the anterior part of the head of the caudate nucleus and another in the region of the genu of the internal capsule beneath the ependyma of the third ventricle.

In order to simplify description the chief changes found microscopically in this region will be divided into three classes. But it must be remembered

that not only did these changes lie side by side, but also that they blended one into the other. Firstly, the most obvious abnormality was the presence of numerous foci of degeneration; secondly, there was a disappearance of nervous elements in the lenticular nucleus; while, thirdly, there was a remarkable cellular infiltration in certain areas.

(1) *Foci of Degeneration.*

Various lesions were observed, but in order to allow of simplification and lucidity of description three main types will be described, namely: (*a*) areas of vascularization; (*b*) areas of fibrosis; (*c*) areas of necrosis.

These three types of alteration were prevalent throughout the lenticular nucleus, and no special area showed an affinity for one type of pathologica

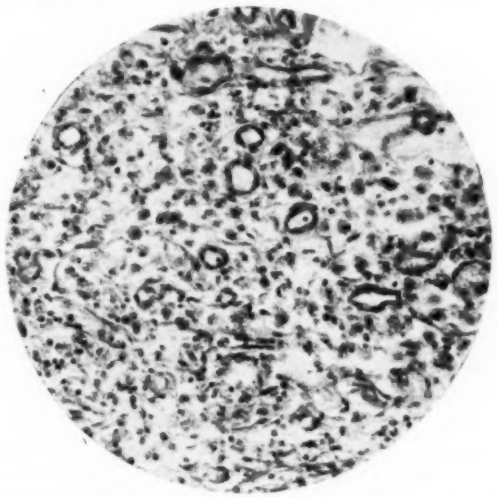

FIG. 1.—Section of lenticular nucleus, showing compound granular corpuscles and capillary network. (Stained with hæmatoxylin and van Gieson.)

process. Undoubtedly, areas in an advanced state of necrosis, as evidenced by the presence of large numbers of compound granular corpuscles, were present chiefly in the centre of the nucleus. As far as could be made out no anatomical relationship to the vascular supply was present.

(*a*) *Areas of Vascularization.*—Throughout the lenticular nucleus the number of capillaries was greatly increased. Under low magnification there appeared a vast network of capillaries, twisting and turning throughout, yet strictly limited to the lenticular nucleus. The capillaries were in many places very fine, usually consisting of a single layer of endothelial cells (fig. 1). This was especially so in close proximity to the areas of fibrosis (yet to be described), and therefore was suggestive of new formation. A few mitotic figures were observed in endothelial cells, suggesting that the vessels were of recent and of

progressively new formation. In proximity to the areas of fibrosis the capillaries had a very fine yet distinct fibrous tissue sheath, but lacked any suggestion of a muscular coat. Round such capillaries there could be observed young glial cells with a lightly staining nucleus, a moderate quantity of protoplasm, and processes extending in all directions but chiefly towards the walls of the vessels. Many compound granular corpuscles were present in these areas, some of which contained blood-derived pigment.

(*b*) *Areas of fibrosis.*—Under a low magnification many small nodules of fibrosis were observed scattered throughout, but occurring chiefly in the anterior and posterior parts of the lenticular nucleus. Higher magnification revealed these fibrotic areas to be made up of a great number of capillary vessels woven together by fibrous tissue. The cells of the fibrous tissue had fair-sized elongated nuclei which stained well with hæmatoxylin; the protoplasm extended into fine processes. At the centre of these nodules of fibrosis the cells lay parallel to the axis of the capillaries, but at the periphery they lay so that they radiated outwards, spreading for some considerable distance. Scattered between the fibrous tissue cells were many compound granular cells, especially where the fibrous formation was least dense.

(*c*) *Areas of necrosis.*—In sections stained by Marchi's method the lenticular nucleus appeared to be in some places almost wholly occupied by compound granular cells. In the centre of the nucleus these cells were in dense formation. It was noticed that in these areas of necrosis practically no nervous tissue elements were present and blood-vessels were very scanty (fig. 1).

(2) *Disappearance of Nervous Elements.*

Sections suitably stained showed a practically complete absence of ganglion cells in the putamen and the globus pallidus. A very few cells of the small ganglion type were observed, equally distributed throughout the essential divisions of the nucleus. Many of these cells, however, presented degenerative changes, in that the nuclei were displaced towards the periphery, and stained less evenly and intensely than normal; the Nissl granules were either diminished in number, or granular and collected towards the periphery of the cells. No definite vacuolation was observed. A few of the remaining ganglion cells were surrounded by neuroglial cells—a state of satellitosis, or compound granular cells were in very close proximity. Myelinated fibres were not observed in any section, though repeated attempts at staining by the Weigert-Pal method were made.

Neuroglial cells, while in excess in some places, were almost entirely absent in other areas.

Around the larger blood-vessels large irregularly shaped neuroglial cells with eccentrically placed nuclei were seen; their cytoplasm was faintly granular and their processes extended out in all directions and were very irregular, some being short and stout, others long and fine. These cells also gave the appearance as if the fine dendritic processes were extending chiefly towards the walls of the blood-vessels (fig. 2). In the immediate vicinity of the

blood-vessels these cells were very numerous; but in regions more remote they became fewer in number.

Around the finer capillaries only a few neuroglial cells were observed, while in the areas exhibiting many compound granular corpuscles only an occasional neuroglial cell was seen. In some areas no neuroglial cells were found whatsoever.

The impression gained from the examination of the neuroglial tissue was that a proliferation of these cells was taking place around the larger vessels to replace the surrounding tissue that had been destroyed.

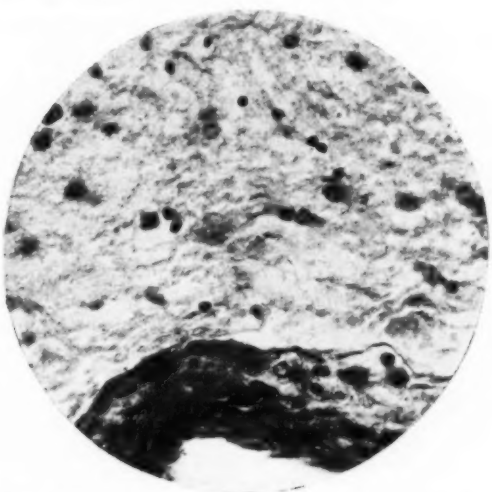

FIG. 2.—Section of lenticular nucleus, showing large neuroglial cells in proximity of large blood-vessels. (Stained with hæmatoxylin and van Gieson.)

(3) *Cellular Infiltration.*

In the region where the ansa lenticularis passes to the subthalamic area a diffusely scattered collection of small round cells was observed. These cells had deeply staining nuclei with a close and dense network of chromatin, and little protoplasm. This infiltration did not appear to be related to any vessel, but it lay in close approximation to the ventricles or cisterns at the base of the brain. Similar round-celled infiltration also occurred under the ependyma covering the thalamus.

In the head of the caudate nucleus two areas of necrosis were apparent. In these areas the nervous tissue had become broken up; the cells had degenerated so that the Nissl granules stained poorly, and the nuclei showed up only faintly. In these areas many compound granular corpuscles were found. Neither vascularization nor fibrosis was, however, apparent. The tail of the caudate nucleus showed no abnormality.

The large ganglion cells of the thalamus were normal in number and character. They stained well by all methods of staining. The smaller type of ganglion cell showed no abnormality. The glial tissue was slightly in excess and a mild degree of satellitosis was present.

The vessels were congested and showed a thickening of the adventitia. They did not appear more numerous than normal. Some of the larger vessels were surrounded by a zone of palely staining granular material. No round-celled infiltration was observed.

The cells of the ependyma itself presented no abnormality. The continuity, however, of the membrane was broken in places by small disc-like protrusions of neuroglial tissue. Where the ependyma was reflected upon itself a marked round-celled infiltration was observed.

Cortex of Cerebral Hemispheres.

Sections taken from various regions of the cortex were remarkable for the changes in the various layers of cells.

The *molecular layer* was slightly deeper than normal and contained many neuroglial cells. Those cells were not especially collected at the periphery, but were evenly distributed throughout the layer.

The cells of the *external granular layer* were somewhat closely packed together and appeared more numerous than normal. They had a small, darkly staining, round nucleus, placed in the centre of a small amount of protoplasm. Repeated staining by Bielschowsky's method failed to reveal any dendritic processes.

There was a gross lack of similarity of the cells of the *pyramidal layer* to those seen in the normal cortex. They were round, with abundant clear-staining protoplasm and contained a small deeply-staining nucleus in an eccentric position. In sections stained with hæmatoxylin and van Gieson's counterstain, the cells were represented by a clear space with a central dark nucleus. Here, too, dendrites and axis-cylinders were demonstrated with the greatest difficulty by methods of silver impregnation. Neurofibrils were not definitely observed in the cell body; as a rule they appeared to be replaced by granules but they were seen in the axons and dendrites. Staining by Scharlach R. failed to reveal any intracellular lipoids. Nissl granules were not satisfactorily demonstrated, though vacuolation was not present.

The cells of the *internal granular layer* were more numerous than normal, being densely packed; they were of uniform type and very similar to those observed in the external granular layer.

An entire absence of the typical ganglion cell was most striking in the *ganglion cell layer*. All the cells appeared to be of uniform size and shape, usually round with a central dark-staining nucleus. No angularity or suggestion of a typical Betz cell was observed in the precentral gyri. In sections stained by Bielschowsky's method a very few fine, fairly large, apparently angular cells were observed; the dendrites of these cells passed an indefinite distance towards the molecular layer, and showed the presence of neurofibrils;

the axons were observed tracking the white matter and no swellings were present in their course. Sections stained to show Nissl granules revealed the presence of some cells in this layer which were rather elongated in shape; the protoplasm appeared very granular, and in no section were Nissl granules satisfactorily demonstrated; the nucleus took on the polychrome blue stain poorly, and the normal central condensation of chromatin was not seen.

The *innermost layer* of the cortex was very indefinite. A few irregularly scattered cells with central dark-staining nuclei were observed intermingling with the ganglion layer, and some extended diffusely into the white matter.

The frontal cortex showed least differentiation into layers, and in it the type of cell appeared to be closely similar throughout. In the precentral and the occipital gyri the cells had sorted themselves out into layers, but they still showed a departure from the normal and resembled those just described. In the region of the hippocampal gyrus the layers were quite clearly distinguishable. The striking abnormality noticed here was a round-celled infiltration, spreading into the hippocampal gyrus from the region of the ventricle. This infiltration was somewhat patchy, but was chiefly localized to the area surrounding the acute flexion of the ependyma of the descending horn of the lateral ventricle.

Myelination.—In the cut section of the brain there was macroscopically a lack of definition between the grey and white matter. The grey appeared of jelly-like consistence and somewhat translucent. Sections stained by Scharlach R. were remarkable for the diffuse distribution of the stain, no myelinated fibres being picked out. We failed repeatedly in staining the white matter of the cortex by means of Weigert-Pal's method (Kulchitsky's modification); repeated attempts did not bring success in any part of the cortex, though control sections took the stain well.

Blood-vessels.—The cortex showed an excess of capillary formation. Many of these small vessels were observed coursing throughout the different layers. In all parts the vessels were congested, but no hæmorrhage was observed. The larger vessels, especially in the white matter, showed slight thickening of the adventitial coat. In places the brain tissue immediately surrounding the vessels stained poorly, showing up as somewhat granular, but no π granules of Reich were observed. Occasionally throughout the various parts of the cortex a mild degree of perivascular infiltration was noticed, but this was in no way marked.

Meninges.—The meninges covering the cortex did not appear to be unduly thick. Round the blood-vessels small collections of round cells containing darkly stained nuclei were observed. In places the adventitia of the vessels was thickened, but the intima and media remained normal.

Base of brain.—Very marked changes were discovered in this region. The meninges were densely matted together with an excess of fibrous tissue (fig. 3). This was especially noticeable in the region of the interpeduncular fossa. Along the side of the blood-vessels of the meninges in this area many small round cells with dark-staining nuclei and little protoplasm were evident No plasma cells were observed.

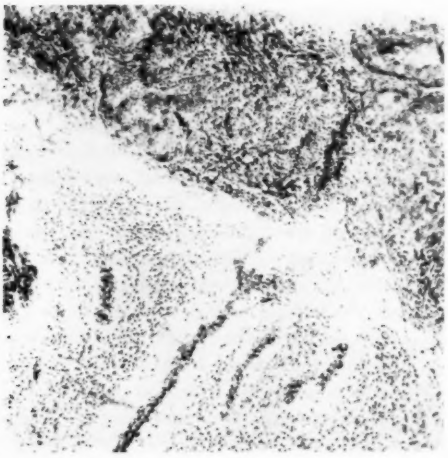

FIG. 3.—Section from base of brain, showing matting together of the meninges. (Stained with hæmatoxylin and van Gieson.)

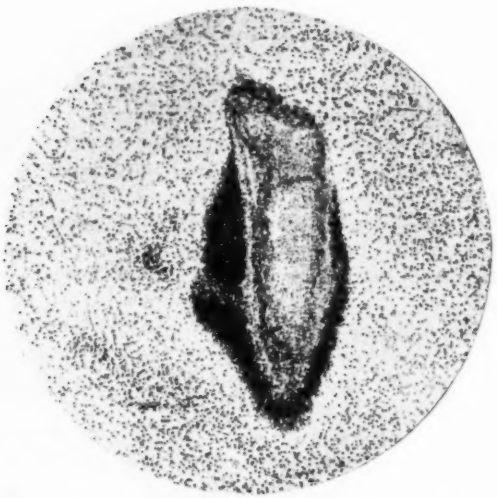

FIG. 4.—Section from region of substantia ant. perforata, showing perivasculur round-celled infiltration. (Stained with hæmatoxylin and van Gieson.)

Passing into the substance of the corpora mamillaria were many fine vessels which were surrounded by an intense round-celled infiltration.

In the region of the anterior perforated substance the blood-vessels showed an extreme round-celled infiltration (fig. 4). A few compound granular corpuscles were also noted in this area. The blood-vessels were deeply congested, but no new capillary formation was observed.

Midbrain.—The pyramidal tracts were not degenerated or infiltrated by cells. The cells of the substantia nigra appeared normal, the Nissl granules staining well. No pigment was observed. The red nucleus showed no abnormality. Slight satellitosis was present in the red nucleus; Nissl granules were well seen in its cells.

The cells of the nucleus of the trigeminal nerve were of the usual type and devoid of any demonstrable pathological defect.

In the region posterior to the aqueduct of Sylvius, at the level of the posterior quadrigeminal bodies, there was a gliosis of recent formation. No ganglion cells were observed. Capillary formation was in excess of normal, but only to a very minor degree. All the vessels were deeply congested, but no hæmorrhage was observed. Round the larger vessels there was an excess of granular material which in sections stained by Nissl's method showed up very pink, suggesting the presence of π granules of Reich.

The ependyma of the iter of Sylvius presented no abnormality.

Pons.—The pontine nuclei appeared to be normal when stained by hæmatoxylin and by Nissl's method. In the region of the motor nuclei of the fifth nerve several small recent hæmorrhages were present. The vessels throughout were deeply congested, but neither round-celled infiltration nor necrosis was evident. The ependyma of the fourth ventricle was normal.

Cerebellum.—The cortex of the cerebellum presented a very interesting condition. Immediately below the surface in the molecular layer was a collection of closely packed cells about eight to nine deep. Those cells were small, had a deeply staining nucleus and closely resembled neuroglial cells. All attempts, however, to stain for neuroglial fibres failed. The remaining parts of the molecular layer appeared normal. According to Ramon y Cajal the presence of many small cells immediately beneath the surface is frequently found during the first few days of life; we may thus assume that the condition in this case was within physiological limits.

The granular layer showed no abnormality. The Purkinje cells were possibly not so numerous as normal and stained less deeply than usual.

The white matter presented no abnormality.

The dentate nucleus contained a normal number of cells, all of which appeared quite healthy.

The blood-vessels were congested throughout the cerebellum, but no new capillary formation and no cellular infiltration were observed. Areas of necrosis were entirely absent.

Spinal cord.—It was impossible to stain sections of the cord by the Weigert-Pal method, as no myelin appeared to be present. In those stained by hæma-

toxylin and van Gieson's method the anterior horn cells gave no semblance of abnormality. The tracts appeared healthy. The ependymal cells of the central canal were normal. The vessels were very congested, and the larger were surrounded by areas of degeneration similar to that described in the other parts of the central nervous system, but to a less marked degree.

The meninges were apparently normal.

Optic nerve and tracts.—Various methods of staining failed to show any deviation from normal.

CASE II. CHAS. S.

A full examination was made eight hours after death. The body was that of a comparatively well-nourished child, aged about 6 months. No deformity was evident. The abdominal and thoracic organs presented no abnormality to the naked eye. The liver was normal in size, shape, colour and consistence. The brain and spinal cord were normal macroscopically; the meninges were not thickened and the cerebro-spinal fluid appeared clear.

Microscopically the kidneys, liver, spleen, pituitary and suprarenals were normal. A section of muscle showed no abnormality.

The brain and spinal cord presented on microscopical examination definite pathological changes which are described below.

Basal Ganglia.

The general configuration of this part of the brain appeared normal in section to the naked eye. In the region of the lenticular nucleus, however, the tissue was soft and pulpy; it easily broke away and had the appearance of being necrotic.

Sections of this area presented very marked changes under the microscope. The areas showing these changes were strictly limited by the internal and external capsules: this demarcation was most striking.

Microscopically two main changes were observed in the basal ganglia, viz.: (1) foci of degeneration; and (2) disappearance of nervous elements.

(1) *Foci of Degeneration.*

Scattered throughout the lenticular nucleus were foci of degeneration of similar types to those found in Case 1.

(*a*) *Areas of vascularization.*—Throughout, the capillaries were much more numerous than normal, and they were all deeply congested. In some irregularly placed areas the capillaries were extremely numerous and close to one another. They ran in all directions and gave no semblance of growing from any central point. They were fine and were made up of a single layer of endothelial cells, in which no mitotic figures were observed. Where the capillaries were most numerous and most densely packed a mild degree of fibrous tissue formation was encountered. Young neuroglial formation was evident in close proximity to the capillaries. The neuroglial cells sent their fibres towards the vessel wall so as to form a surrounding palisade of glial fibres.

(*b*) *Areas of fibrosis.*—As the capillaries became collected together into clumps they were bound together by fibrous tissue. This gave the appearance in the sections of small areas of fibrosis. These semi-nodular areas of fibrosis were not confined to any one area of the nucleus, but appeared more commonly in its anterior and posterior parts. The cells of the fibrous tissue ran more or less parallel to the coats of the small vessels, but in places tended to radiate outwards.

(*c*) *Areas of necrosis.*—The whole nucleus was densely packed with compound granular corpuscles which collected in masses where the capillary network was particularly dense. In some areas almost complete necrosis had taken place, leaving a homogeneous mass of material in which disintegrating cells with ill-staining nuclei were present. These areas were more particularly situated towards the centre of the nucleus.

The larger blood-vessels in the lenticular nucleus showed great thickening of their adventitial coat, so that they were encircled by a ring of fibrous tissue. In places the surrounding brain tissue had apparently contracted away, leaving a comparatively clear area surrounding the thickened vessel wall. No definite perivascular infiltration was observed.

(2) *Disappearance of Nervous Elements.*

In the lenticular nucleus there was an almost entire absence of nervous elements. Only a very few ganglion cells were observed, scattered irregularly throughout the nucleus and varying in number according to the section. When present they stained somewhat indefinitely, showing an entire absence of Nissl granules and a poorly staining, eccentrically placed nucleus.

Myelinated fibres were almost entirely absent. A few ill-staining medullary sheaths were shown by the Weigert-Pal method, but it was impossible to trace their direction. In all sections stained for myelin the whiteness of the lenticular nucleus was most striking.

Caudate nucleus.—No marked degenerative change was observed in this nucleus, but a small area of capillary formation appeared towards the posterior part of its head. This vascularization had the appearance of having pierced the internal capsule. A few compound granular corpuscles were present in the immediate vicinity of the new capillary formation.

Thalamus.—The large ganglion cells were few in number but appeared quite healthy. The smaller type of ganglion cells were very numerous. Overlying and surrounding some nerve cells a few glial cells were observed. The vessels were congested, yet there was no excess in the number of capillaries. The glial tissue was rather more abundant than normal.

At both the extreme upper and lower limits of the thalamus where it narrows down on to the internal capsule were two small areas showing numerous compound granular corpuscles; a few fine capillaries were present in these areas.

No round-celled infiltration was observed in the thalamus itself; but in the

glial tissue immediately underlying the ependyma small round cells were numerous.

Ependyma.—The ependyma lining the ventricles appeared normal. The continuity of the layer of ependymal cells covering the thalamus was broken in several places by small flat disc-like protrusions of tissue resembling neuroglia, but these areas were very few and small.

Beneath the ependyma there was some thickening of neuroglial tissue and a mild degree of round-celled infiltration. This was especially marked at any places where the ependyma was acutely flexed upon itself, as in the anterior part of the lateral ventricles.

In the region of the hippocampal gyrus the round-celled infiltration was fairly well marked but there was no lack of continuity of the surface. That lining the iter of Sylvius and the fourth ventricle appeared quite normal without any subependymal infiltration.

Cortex of Cerebral Hemispheres.

In sections taken from different regions of the cortex and stained with alum hæmatoxylin and van Gieson's stain, the various layers of the cortex were at once discernible. But closer examination showed that the cells constituting these layers departed from normal both as regards number and type.

The *molecular layer* was composed of an average number of small rounded cells; no undue thickening of the layer nor aggregation of cells in the peripheral region was observed. By means of suitable staining methods the terminal dendrites of a few of the pyramidal cells were observed to terminate within the layer.

The cells of the *external granular layer* exhibited a dark-staining nucleus with very little protoplasm. By Bielschowsky's method of staining the cells showed little resemblance to those known as Golgi Type II; the dendrites were short and very fine with little or no branching. Only an occasional fibre was observed passing out into the molecular layer.

The *pyramidal layer* showed a diminution in the number of cells as compared with the normal. The cells, in hæmatoxylin-stained sections, appeared as round clear areas with an ill-staining nucleus having a loose reticular network of chromatin. The nucleus was occasionally oval but generally rounded. The dentrites passed towards the periphery and contained neurofibrils. The axons showed the presence of neurofibrils, but in the cell itself no neurofibrils could be demonstrated, their place being taken by granules which were collected chiefly in the outer zone of the protoplasm. Sections stained by Bielschowsky's method brought out the fact that some of these cells were definitely angular. No collection of lipoid material was observed in the cells and no swelling of the axon near the mother cell appeared in the sections examined. The Nissl granules showed up indefinitely, appearing to be more granular than flake-like.

The cells of the *internal granular layer* closely resembled Golgi Type II cells. They had a deeply staining nucleus.

In sections stained with hæmatoxylin and van Gieson's stain there appeared to be an entire absence of typical ganglion cells in the *ganglion cell layer*. The cells were very few in number though large compared with those of the other layers. They appeared as large clear areas with eccentric nuclei staining less deeply than the nuclei of the cells in the other layers. The chromatin network was of wide mesh with many knots. The cells were devoid of Nissl granules. Silver impregnation methods brought out the fact that there were a few large typical ganglion cells; the dendrites and axons of these showed neurofibrils, but the protoplasm of the cells themselves contained only dark-staining granules. No lipoid material staining with Scharlach R. and no swelling of the axons were observed.

The cells of the *innermost layer* appeared rather less numerous than normal, though they closely resembled the type normally found. Throughout there appeared to be no excess of neuroglial tissue.

The regions of the cortex showing the most profound changes were the precentral gyri and the occipital lobes. In the former the paucity of typical ganglion cells was notable, while in the latter the diminution in their number was slight. The frontal cortex and that in the region of both angular gyri and the hippocampal gyri showed changes in the cells of a less intense degree than elsewhere.

Myelination.—Using the Weigert-Pal method of staining, sections from the cortex stained unsatisfactorily although controls from other cases put through the same solutions stained perfectly. In all regions of the cortex the staining of myelin was deficient. The medullary sheaths showed marked irregularity in calibre and at places definite globular formation. Only a very few myelinated fibres could be traced out into the cortex as far as the ganglion layer of cells.

Sections of the cortex stained by Scharlach R. in a diffuse manner, and did not bring the medullary sheaths into prominence.

Marchi's method showed no stippling of the fibre tracts.

Blood-vessels.—Throughout the cortex the blood-vessels were very congested, but no pathological vascularization was observed. The smaller vessels showed a slight thickening of the adventitial coat around which the brain tissue stained less deeply with hæmatoxylin and appeared granular. With Nissl's stain this surrounding granular area took on a pinkish colour and was in places definitely occupied by rhomboidal pink granules, very similar to the π granules of Reich. In many places the brain tissue appeared to have contracted away from the blood-vessels.

In the occipital cortex a mild degree of perivascular round-celled infiltration was present; and in one section of the same region a small hæmorrhage in the ganglion layer was observed. Marchi's stain of the cortex brought to light the presence of fatty material along the sides of the vessels, in the white matter especially; this was particularly noticeable in the precentral and occipital regions and more especially in the white matter underlying the cortex.

Meninges.—Slight thickening of the pia mater and arachnoid was observed throughout. No cellular infiltration was present. The blood-vessels of the

meninges showed thickening of the elastic lamina and also of the adventitial coat. No changes in the intima were observed.

The meninges covering the base of the brain, especially in the region of the hippocampal gyri and covering the basis pedunculi, showed marked thickening and fibrous formation. A considerable degree of round-celled infiltration was noted, especially round vessels and extending into the midbrain. No plasma cells were observed.

Mesencephalon.—In sections of this region the pyramidal tracts and nuclei appeared normal.

The substantia nigra showed similar degenerative processes to those seen in the lenticular nucleus. This area was highly vascular and congested. Many compound granular corpuscles were present in it, but no fibrosis was observed. In spite of the juxtaposition of the degenerative processes the cells of the substantia nigra showed little abnormality except a mild degree of satellitosis. Practically no pigment was present and when observed it was always lying outside the cells.

Pons and medulla oblongata.—The nuclei of the cranial nerves showed no abnormality. There was no degeneration of tracts, but the root of the seventh nerve as it passed outwards showed slight stippling by Marchi's method of staining; this might have been accounted for by post-mortem artefact as a result of traction on the nerve. The nuclei pontis appeared quite normal, except in one small area where a marked increase in capillary formation and a few compound granular corpuscles were present. This area was localized to the upper part of the pons on the left side. There was marked congestion throughout with a tendency for a perivascular degeneration and formation of π granules of Reich, similar to those described as occurring in the cortex.

Cerebellum.—No abnormality was detected other than the presence of a very few widely-scattered compound granular corpuscles in the molecular layer immediately beneath the surface. No collection of compound granular cells was observed along the blood-vessels.

Spinal cord.—The tracts appeared well myelinated; the afferent tracts stained more deeply and appeared to be better myelinated than the efferent tracts. No degeneration was observed by Marchi's method of staining. The anterior horn cells appeared normal in number and distribution.

The blood-vessels were congested. In sections stained by Nissl's stain the area immediately surrounding the blood-vessels took on a pinkish colour due to the presence of π granules of Reich. The adventitia of the vessels was slightly increased.

Optic nerve and tracts.—No change from the normal could be observed in the architecture of these structures. Myelination was perfect. There was no excess of neuroglial tissue or any round-celled infiltration, and no degenerative process was observed.

Résumé of the Pathological Findings.

Pathologically, the two cases described above showed changes in the central nervous system which were remarkably similar in nature and which differed in degree only.

(1) The lenticular nuclei in both cases showed an almost entire absence of nervous elements. The ganglion cells were practically absent and very few myelinated fibres were present, and these stained very poorly. The nerve tissue of the nucleus was largely replaced by compound granular corpuscles. Coursing throughout the nucleus were many fine, deeply congested capillaries, which were of recent formation and were still being actively formed, as evidenced by the presence of mitotic figures in the endothelial cells. In places fibrous tissue overgrowth had knitted together the various capillaries; in other places young neuroglial cells were found. The degree of change in both cases was nearly similar, but in the elder child there was, if anything, more neuroglial and fibrous tissue. The striking fact was the almost complete limitation of these changes to the lenticular nucleus. Only one or two very small areas of degeneration were found in the head of the caudate nucleus.

(2) The round-celled infiltration at the base of the brain and involving the structures surrounding the interpeduncular fossa was striking. This round-celled infiltration was seen to spread, in the child which only lived a few hours, along the vessels of the anterior perforated substance up into the region of the basal ganglion, The meninges at the base were thickened, matted together and exhibited a mild degree of cellular infiltration. The older child had less well-marked changes in the membranes.

(3) The cerebral cortex in both cases, though presenting layer formation, consisted of cells not only ill-formed but actively degenerating. This was evidenced by the poor staining properties, the granular protoplasm of the cells, and the presence of compound granular cells along the blood-vessels. Thus one may say that the cortex showed both a maldevelopment and an active degeneration.

(4) Defective myelination was observed in both cases, being more marked in the early case. There appeared to be an almost total absence of tangential and radiating fibre systems, and the white matter stained very poorly and irregularly in both cases.

(5) Areas of degeneration were observed in the crura cerebri and pons. The region of the substantia nigra appeared to be particularly affected, though there was no actual destruction of the ganglion cells of the nucleus itself. This was more apparent in the older of the two children.

(6) The blood-vessels throughout showed a slight increase in the adventitial coat and an immediate surrounding area of degeneration of nervous tissue as shown by the presence of π granules of Reich.

(7) A careful scrutiny of the sections failed to reveal the presence of any plasma cells. Moreover sections stained specially also failed to produce evidence of their presence.

Interpretation of Lesions.

Allow us first to explain the significance of the various lesions found in the pathological examination of these two cases.

The large number of compound granular corpuscles, the degenerated condition or even complete absence of nervous tissue elements, and the new capillary formation found in the lenticular nucleus suggest that the changes have been brought about by ischæmia. The presence of cells containing blood pigment in the affected area enhances this conclusion. It is evident from the neuroglial proliferation and the network of capillaries interwoven by fibrous tissue that repair has commenced. One may assume therefore that the ischæmia has only been relative and not absolute. There was, however, an absence of a peripheral zone of neuroglial activity as is frequently found in patches of softening of the brain. The presence of new capillary formation with a knitting together by fibrous tissue at once raises the question of the age of the ischæmia. From the appearance described one cannot but decide that the ischæmic process had commenced some considerable time before death; this particularly refers to the child who only lived a few days.

The small-celled infiltration at the base of the brain which spread up into the lenticular nucleus demands explanation. In considering the cellular infiltration one must take into account the nature and number of cells. The cells were very numerous and were found chiefly in the perivascular zones; they were of the small, round-celled type, with deeply staining nuclei. Not only did this cellular infiltration affect the brain tissue but it was present also in the meninges. Again, the meninges were matted together. These points are all in favour of some inflammatory process. But it is unusual to find an entire absence of plasma cells in any subacute inflammatory condition of the central nervous system. Could the round-celled infiltration be explained on the basis of a degenerative condition? Their numbers and the matting together of the meninges are against such an assumption.

Throughout the cortex and spinal cord the blood-vessels were found to have an area immediately surrounding them which stained palely

and appeared to be granular. This change is very suggestive of a toxic process being at work; and one is led to assume that the toxin was in all probability circulating in the blood-vessels.

The lesions found in the cortex, namely, the poor staining qualities of the ganglion cells and the absence of the usual marked differentiation between the various cells, may be interpreted as being due to a certain degenerative change and an associated maldevelopment of the cortex. The degenerative changes are probably due to the circulatory toxin which has already been postulated as a cause of the perivascular necrotic areas of brain tissue.

The defective myelination found in both cases allows of only two possible explanations, namely, either maldevelopment or degeneration. Only a very few compound granular corpuscles were found along the blood-vessels of the white matter; this being so, one is forced to exclude a purely degenerative process and to conclude in favour of a maldevelopment.

Reviewing the interpretations given to the various lesions found on the microscopical examination of these cases it may be assumed that there were present:—

(1) An inflammatory process at the base of the brain and involving the meninges.

(2) An ischæmic condition of the lenticular nucleus.

(3) A maldevelopment and degeneration of the cortex.

(4) A maldevelopment of the myelin formation.

(5) A perivascular degeneration of toxic origin.

Discussion.

The remarkable similarity in the pathological findings in the two cases leads one to pass from the realms of fact to those of speculation.

Is the lesion syphilitic? The entire absence of plasma cells and the negative Wassermann reaction in the children and parents absolutely preclude such a possibility.

Is the condition found compatible with an organismal infection? In favour of this, attention may be drawn to the very marked round-celled infiltration at the base of the brain, especially in the younger child, and the matting together of the meninges. But the degeneration of the cortex and the perivascular areas of destruction of nervous tissue raise the question as to the presence of a circulating toxin. In the opinion of the observers the degree of round-celled infiltration at the base of the brain is not compatible with a purely toxic cause. One is therefore bound to conclude that an infective organismal state at the

base of the brain has occurred with a consequent toxæmia which affected chiefly the cells of the cortex.

The onset of the organismal invasion must have occurred previous to birth, because in the child which only lived a few hours the changes found were too advanced to have been produced during extra-uterine life. The marked necrosis, as evidenced by the large number of compound granular cells, and the large number of capillaries with fibrous tissue formation knitting them together, confirms this statement. The conclusion in favour of the infection being antenatal is enhanced by the fact that the mother suffered from a chronic endometritis for the past seventeen years, and as this septic focus has been present throughout all her pregnancies it seems reasonable to count this the probable source of infection. It is difficult to estimate exactly when the infection took place, but from the nature of the changes found in the cortex of the younger child it must have occurred some weeks previous to birth.

Unfortunately the placenta and cord of the younger child were not examined microscopically. Had this been done the route of infection might have been traced. It is suggested, however, that the infection has arisen from the chronic endometritis, passed by way of placenta and cord to the fœtus and there set up a basal meningitis. A swab from the uterus of the mother has not been taken, permission for such an examination not being permitted, and so the causal agent still remains unknown. No organisms were found in the sections of the brain or meninges, so that no further clue has been gained as to the character of the infection.

Could the lesions be explained on the basis of an encephalitis lethargica *in utero*? No evidence is forthcoming to show that the lesions in any way resembled those found in encephalitis lethargica. The absence of plasma cells and the capillary formation with surrounding necrosis have never been recorded in this disease.

If we assume that the cause is organismal, the fact that the first child lived to the age of seven months showed that the organism cannot have been actively virulent; and one is justified in deducing from the rather less marked degree of round-celled infiltration and the greater attempt at repair in the lenticular nucleus in the older child, that the infection was being gradually overcome or was losing its virulence.

Thus summarizing, we submit that the pathological examination revealed the presence of an infective organismal state of the base of the brain, of antenatal origin and probably arising from the endometritis from which the mother was suffering.

One must next attempt to explain the sequence of the lesions found.

One point of special interest arises here. Why is it that the lenticular nucleus has received the most damage?

Many possible solutions may be quoted in answer to this problem. In considering it one is forced to face the possibility of a selective action for the lenticular nucleus on the part of the causal agent. Now it is known that in certain cases of icterus gravis neonatorum the basal ganglia, and especially the lenticular nucleus, are stained more yellow than the rest of the brain tissue; on microscopical examination, however, the pigment is found to be intracellular. Again, in his work on progressive lenticular degeneration, Wilson [9] concludes that "the degeneration is the sequel to the selective operation of some morbid agent on the cells and fibres of putamen and lenticular nucleus generally." In carbon monoxide poisoning the chief changes occur in the lenticular nucleus. Here is sufficient evidence in other diseases to allow of the possibility being invoked that the degeneration in the cases described is a result of selective action.

But it is hard to explain how an organism causing a basal meningitis can elaborate a toxin which has a purely selective action on the lenticular nucleus. A degeneration of the cortex and also in one of the cases in the mesencephalon, precludes such a supposition.

In discussing the answer to this question anatomical factors must be reviewed. They may be looked at from several standpoints, namely, the arterial supply, the venous return, the density of the tissue and the presence of Virchow-Robin spaces. Lastly, the phylogenetic point of view must be considered.

Stewart [7] has pointed out that in carbon monoxide poisoning marked degenerative changes are found not only in the lenticular nucleus, but also in the middle layers of the cortex where the pial vessels end. He therefore attempts to explain the lenticular destruction on a basis of defective arterial supply. He brings forward in favour of his theory the fact that the arteries to the nucleus come off at right angles from the larger vessels, run upwards, and then again bend sharply upon themselves. He therefore suggests that a degree of kinking and stagnation may cause a relative ischæmia, with consequent damage to the lenticular nucleus. Can this theory alone explain the degeneration present in the cases described? One must but allow that it may only be a factor and not an absolute cause.

The veins returning from the nucleus run upwards into the vena terminalis which they join at right angles. The vena terminalis runs forward in the groove between the caudate and thalamus to join the internal cerebral vein at the anterior end of the septum pellucidum,

where it turns acutely upon itself. Can there be a cause for retardation or venous return? No evidence of this is forthcoming in our two cases though the vessels were all deeply congested—a congestion more easily explained on an inflammatory basis.

The basal ganglion cannot be said to have structure less strongly woven together than the rest of the brain, nor are the vessels less well supported.

It is known that the potential space surrounding the vessels entering the brain tissue are bathed with cerebro-spinal fluid. In these two cases there was evidence of a basal meningitis with matting together of the meninges. Could this have caused a mild distension of the Virchow-Robin space around the vessels leading from the area of meningitis? The suggestion that such an event might occur with a consequent stagnation of cerebrospinal fluid nourishing the basal ganglion is within the sphere of credulity. But in the two cases examined the vessels did not all show cuffing, and no vessels showed a distension of the Virchow-Robin space—the round-celled infiltration being outside the aforesaid space.

The area degenerated involved both a part of the neo-striatum and the palleo-striatum. This at once removes the phylogenetic theory as a possible factor in the pathogenesis.

Reviewing all the possibilities, one is forced to conclude that in the two cases described a basal infection had taken place, that it spread along the vessels to the basal ganglia through the anterior perforated substance and also into the crura cerebri, and that a relative ischæmia resulted with consequent degeneration of the tissues in the areas supplied by these vessels.

Let us next briefly refer to the condition of the cortex. How has such a degeneration arisen? We have already assumed that a general circulating toxin must have been present, for the areas surrounding the blood-vessels which stained pink by Nissl's stain, are, according to Reich, significant of a degeneration of toxic origin. Therefore, one may postulate that the cerebral cortex reached a certain stage of development *in utero*, and that it was then attacked by a toxin which caused degeneration of the cortical cells to set in.

Relationship of this Disease to other known Conditions.

One may ask whether the cases described show any resemblance to other diseases of the brain. In answer permit us to review the possibilities.

(*a*) Congenital syphilitic meningitis has many points in similarity,

but, as has already been expounded, these cases are definitely not syphilitic in origin.

(*b*) Encephalitis lethargica *in utero* is a doubtful possibility; some German observers have described cases, but the lesions found in our two cases do not correspond to those described as encephalitis lethargica *in utero*. Further, it is unlikely that the mother would have been able to transmit the disease to her offspring during a period of fifteen years.

(*c*) Progressive lenticular degeneration is a disease commencing in young adult life and, according to Wilson, is not congenital in origin. It is identified with cirrhosis of the liver which causes no symptoms during life. Our cases showed no abnormality of the liver and also commenced previous to birth. No relation between our cases and progressive lenticular degeneration is evident [9].

(*d*) Vogt [8] has carefully described various lesions of the basal ganglion. The "état fibreux" and "état marbré" have occurred in people who have long survived the first few months of life. However, is one justified in venturing to suggest that, had these children lived for some years, the lenticular nucleus might have become completely fibrosed? This suggestion is not without a foundation, for areas of fibrosis were found in the lenticular nucleus of both of our cases and were more marked in the older child. Vogt states that asphyxiation is to be counted a primary factor in the causation of the "état marbré." In our cases no asphyxia was present at birth and the umbilical cord was not twined round the neck in either case. The state of the perivascular nervous tissue in the two cases resemble the "état précriblé" of Vogt: he, however, described this condition as one in close connection with arterio-sclerosis [8].

(*e*) Several German writers have collected cases of icterus gravis neonatorum. Have the cases in this paper any points resembling those of severe jaundice? It is admitted that all the children who lived for more than a few days were slightly jaundiced for a short period of time. But we may lay no stress on this, as a mild jaundice is very common in newly-born children and causes no late symptoms. It is also quite definite that these children described by us did not suffer from the grave jaundice of the newly-born [1] [3] [5] [6].

(*f*) Can we draw any comparison between cases of cerebral diplegia and our cases? To our knowledge no lesion has been found in cerebral diplegia corresponding to those described in this paper. But we know of no careful and minute histological examination of the basal ganglia,

especially in those cases where the brain appeared macroscopically normal. In our cases progressive mental deterioration was prominent; whereas in cerebral diplegia mental improvement is the rule and progress is made throughout life. Unlike our cases cerebral diplegia is not familial. These two fundamental differences make it certain that no relation to cerebral diplegia exists in our two cases. Dr. Collier [2] states that in his opinion cerebral diplegia is due to a primary neuronic degeneration. In our cases degeneration of the cortex has taken place, but is of such a nature as to leave the cause undoubted. Not all cerebral diplegias show signs at birth, but in those that do could not the lesion be due to a circulating toxin, possibly maternal in origin?

(*g*) In the Waren Tay-Sachs type of cerebral degeneration marked changes in the lipoid content of the cells is evident. No such anomaly was found here, and one may definitely state that no relation exists to this type of cerebral degeneration.

(*h*) Pellagra gives rise to progressive cerebral degeneration. No evidence, however, was forthcoming either clinically or pathologically in our two cases to suggest such a diagnosis.

(*i*) In carbon monoxide poisoning the globus pallidus may be filled with very numerous "Körchenzellen": the neuroglial tissue is in excess and the nerve cells have either disappeared or are in a state of decay. Associated with this there is a profound disturbance of the myelin, and the middle layers of the cortex show degenerative changes. Undoubtedly there is here a resemblance to our cases; but the presence of round cells in large numbers and new capillary formation preclude such a diagnosis.

(*j*) At the meeting of the American Neurological Association held at Boston in June, 1923, Stanley Cobb and Hugh Mella read a paper entitled "The Experimental Production of Basal Ganglion Symptomatology in *Macacus rhesus*" [4]. Manganese chloride was administered to several monkeys upon which at a later date post-mortem investigations were carried out. A cirrhosis of the liver was found, while in the globus pallidus vacuolation of the large pallidal cells and areas of gliosis were encountered. The findings of these observers in no way resemble what was found in the two autopsies described in this paper.

We, therefore, bring forward the supposition that we are dealing with a condition which has not been described before and which cannot be placed in any of the aforesaid categories.

The Relation between the Clinical Symptoms and the Pathological Findings.

Both children appeared blind though the light reflex was still present. Pathologically no abnormality was detected in the optic nerves or tracts; unfortunately the eyes were not removed, but ophthalmologically they were normal. However, the occipital cortex was poorly developed and showed signs of degeneration; this would be sufficient to account for the blindness, which was therefore cerebral in origin.

The absence of increased tone, such as one associates with lesions of the extrapyramidal system, may be explained by the atrophy of the precentral gyrus and the poor myelination of the white matter throughout.

Conclusions.

There is a condition of cerebral degeneration which presents the following characteristics:—

(*a*) It is familial.

(*b*) Clinically it gives rise to apathy and apparent blindness without changes in the fundi of the eyes.

(*c*) There is an absence of paralysis and abnormal movements.

(*d*) The children live from 2 to 6 months, and occasionally up to 2 years of age.

(*e*) It is probably due to an intra-uterine infection.

(*f*) The severest pathological changes are found in the lenticular nuclei, while the cortex is badly developed and degenerated.

We desire to express our indebtedness for kindly criticism and advice to Dr. James Collier, Dr. S. A. K. Wilson, and also to Dr. J. G. Greenfield, in whose laboratory the pathological investigations were carried out. To Dr. Hodgson-Jones, of Caterham, our thanks are due for help in collecting the history.

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Proceedings of the Section of Neurology of the Royal Society of Medicine.

President—Dr. JAMES S. COLLIER.

Clinical Meeting held at the Hospital for Epilepsy and Paralysis, Maida Vale, W., on January 10, 1924.

Case of Myopathy confined to the Face.

By Dr. JAMES COLLIER.

W. H., a hammerman, aged 36, has never in his memory been able to close his eyes or to use his lips. He was told by his sister when a child that at birth both sides of his jaw were broken and that his peculiar facial appearance was the result.

There is complete atrophic paralysis of all the muscles of the face, excepting a few fibres of the retractors of the right angle of the mouth. The "myopathic" face is very typical. He speaks as a ventriloquist, but his enunciation is very fair except for the labials. The ocular, trigeminal, lingual muscles and the muscles of the neck, body, and limbs seem perfect. He has always been able to work hard at a laborious occupation.

No change has taken place in the condition of his face in his memory. He has an old traumatic cataract due to a perforating wound of the cornea on the left side. There are no signs of myasthenia nor of myotonia.

Cases of persistent bilateral obstetrical facial palsy have been reported by Duchenne; also by Edgeworth (*British Medical Journal*, 1894, i, p. 11).

Dr. KINNIER WILSON said it was quite possible the case in reality was one of congenital nuclear defect—the "infantile Kernschwund" of German writers. Much depended on the exact clinical history in these cases, but he was of the opinion that obstetrical injury to the jaw, as stated by the patient's sister, would not explain the absolute facial diplegia from which the patient suffered.

Dr. COLLIER said that it certainly was not one of bilateral obstetrical facial paralysis. There were no signs whatever that the jaws had been injured at birth. He suggested that the story given by the patient's sister was one of the commonly occurring examples of a fable put forward to explain a little understood fact. He was obliged to Dr. Wilson for his suggestion, which he was willing to accept as the real explanation of this case, the more so since such movement as was present in the right side of the face was much more easily elicited on emotional movement than on volitional attempt.

A Case of Myotonia Atrophica.

Shown by Dr. J. P. MARTIN (for Dr. WILFRED HARRIS).

E. C., unmarried woman, aged 38.

Family history.—Cataract in paternal grandmother; cataract in father and in three of his sisters. History suggestive of myotonia in one of the patient's brothers now dead.

History.—About 1912 the patient's face became very thin and never filled out again. During the last eight years occasional spasm of the tongue during conversation, and for about five years spasm of the hands after grasping anything tightly. About two years ago the lower limbs began to waste, and they are still getting thinner and weaker. Six months ago she felt the right leg numb, and later the numbness spread up to the middle of the leg.

Present state.—Advanced wasting of the muscles of the face, neck, forearms, thighs and legs; all the musculature of the body is very small. Myotonia on voluntary movements in the tongue, masseters, muscles involved in the hand grasp and in some of the muscles of the lower limbs. Myotonic reaction to percussion in the muscles of the upper arms and shoulder-girdle.

Eyes: A few dust-like opacities in both lenses. Fundi normal. Pupils react poorly to light.

Circulatory system: Heart sounds normal. Systolic blood-pressure: 98 mm. mercury, and diastolic 66 mm. mercury.

Genito-urinary system: Free creatine is present in the urine. Menses irregular, every third or fourth month; menstruation did not begin till she was 18 years of age.

Nervous system: Tendon-jerks all absent; superficial reflexes normal. No disorder of the cranial nerves. On admission to hospital there was a loss of appreciation of pain and touch stimuli ever the right foot and lower part of the right leg, but this was dispelled by Dr. Harris by the use of suggestion and faradism.

Case of Tumour of the Acoustic Nerve.

By Dr. C. WORSTER-DROUGHT.

F. G., female, aged 37.

History.—About April, 1921, the patient began to complain of deafness in the right ear and numbness on the right side of the face, the two symptoms appearing almost simultaneously. During the past two years the facial numbness has increased only very slightly, but the deafness has become more pronounced. Other symptoms that have been noticed from time to time are as follows: (1) In addition to right facial numbness, occasional tingling sensations on the right cheek, margins of the lips, and on the right side of the tongue. (2) Occasional tinnitus—described as "buzzing in the head"—which tends to become more constant. (3) Occasional vertigo and, more recently, a tendency to stagger on turning quickly or upon rising from the lying-down

position. (4) Transient twitching of the right side of the face. (5) Attacks of nausea and vomiting of short duration at long intervals, and, more recently. (6) Occipital headaches. The symptoms, however, do not prevent the patient from carrying on her work as a clerk, nor from enjoying life even to the extent of dancing.

Physical examination.—Pupils normal, reactions normal; fundi and fields of vision normal. Rhythmical nystagmus upwards and outwards on deviation of eyes to right (towards lesion); ocular muscles otherwise normal. Motor functions of fifth nerve not impaired; relative conjunctival anæsthesia; large area of anæsthesia and analgesia to cotton wool and pin-prick on the right side of face extending from the eye to just below the corner of the mouth, forwards to the margin of the nose and backwards to the anterior border of the masseter muscle. The area of loss of sensibility to pin-prick is larger than, and encloses that to, cotton-wool (root anæsthesia). Facial movements normal. Eighth nerve: complete nerve deafness on right side, confirmed by noise-machine to left ear and other tests. Labyrinthine reactions: total absence of vertigo, nystagmus and past-pointing to cold air test on right side, both for horizontal and vertical semicircular canals; normal labyrinthine reactions on the left side; the galvanic reaction is also absent on the right side. (The case was also examined by Sir James Dundas-Grant, who considered that there was a lesion of the trunk of the auditory nerve internal to the labyrinth.) Tongue: movement normal; sensation and taste are diminished over the anterior two-thirds of the right side. Arm-jerks, abdominal and plantar reflexes, knee- and ankle-jerks are all normal. No inco-ordination or tremor of hands; no dysdiadokokinesia. When placed in the Romberg position there is a tendency to fall towards the right side; the same tendency is seen when the patient turns suddenly or rises from the lying-down position. Other systems are normal. The antra of Highmore and accessory nasal sinuses show no abnormality. Wassermann reaction in the blood serum is negative. Radiographic examination reveals no abnormality in the basal regions of the skull.

Dr. WORSTER-DROUGHT said that the symptoms and signs in this case indicated a relatively early tumour of the acoustic nerve. An interesting feature was the simultaneous development of symptoms pointing to the involvement of the eighth and fifth nerves. The only indication of seventh nerve affection was the occasional twitching, due to irritation of the nerve. As with most cases tinnitus was late in appearance and was not constant. Apart from the nystagmus the only sign of cerebellar involvement was the tendency to lose the balance and fall to the right.

Dr. COLLIER (President), in reply to Dr. Worster-Drought's question as to treatment, said that he did not think it advisable to attempt removal of the tumour as long as this patient was able to enjoy life fully and was suffering so little inconvenience from its presence.

Case of Friedreich's Ataxia with Double Optic Atrophy.

By Dr. C. WORSTER-DROUGHT.

G. Y., aged 23, complains of general nervousness, inability to keep his limbs still, and defective vision.

History.—The above symptoms have been present ever since the patient can remember, but appear to have become recently worse. Birth was accompanied by difficult labour, his mother being in labour for five days; no instruments were used. He did not walk until the age of 1 year and 10 months, and at 4 years had a severe fall down a flight of stairs, sustaining concussion; following this he did not walk for nine months. His mother thinks that his defective vision dated from this time; she has noticed nothing else beyond the fact that he is nervous and "fidgety."

Family history.—His father (killed in the Great War) suffered at very long intervals from "fits," the description of which suggests epilepsy. The patient has one sister, aged 21, who is quite healthy. His first cousin (paternal side), aged 20, is in a mental institution and is believed to be hydrocephalic. Otherwise there is no family history of nervous disorder.

Physical examination.—Pupils: equal, central, regular and react normally. Fundi: double primary optic atrophy. Continuous nystagmus. Facial expression somewhat "passive." Other cranial nerves normal. Arm-jerks brisk and equal. Abdominal and epigastric reflexes brisk and equal. Knee-jerks present and equal; ankle-jerks absent. Plantar reflexes: left flexor; right indefinite, mainly extensor. Atrophy of all intrinsic muscles of both feet with pes cavus. Sensation (cutaneous and deep) normal. Co-ordination: arms (finger-nose test, &c.) normal. No intention tremor. Some difficulty in performing rapidly alternating movements of the arms and hands (dysdiadokokinesia). He tends to walk on rather a wide base, with slight ataxia, and exhibits a certain degree of Rombergism. Continual "restless" movements of head and limbs. Wassermann reaction negative in blood-serum. Cerebrospinal fluid: 5 lymphocytes per c.mm., globulin and Wassermann reactions negative.

Dr. WORSTER-DROUGHT remarked that the combination of signs in this case pointed to a diagnosis of Friedreich's ataxia, while the choreic restlessness described in this disease was a pronounced feature. He had brought this case before the Section on account of the extreme rarity of optic atrophy in this disease. Most authorities stated that it did not occur. Cases however had been recorded by Ormerod, Taylor, Cohn and others. All these cases had been quite typical in all other respects.

Dr. COLLIER (President) was of the opinion that this case was not one of Friedreich's disease, but that it belonged to the class of complicated peroneal atrophy. He said he had observed a family in which many members suffered with peroneal atrophy, complicated with optic atrophy and other signs unusual in that disease. The condition of the feet in this case was not one of pes cavus. They were simply dropped feet from muscular wasting. He had

shown many years ago that there was no atrophy of the intrinsic muscles of the feet in the pes cavus of Friedreich's disease. In Dr. Worster-Drought's case there was extreme atrophy of the muscles below the middle of the leg.

Symptoms following Encephalitis Lethargica.

By Dr. H. CAMPBELL THOMPSON.

A. S., woman, aged 40. Was ill in May, 1923, for about five weeks, but remembers nothing of this period. On getting up her vision was so defective that she knocked against things. Moving about, and any change of light, made her dazed and confused. She has had attacks of asthma for several years.

Her memory is very defective; she displays little interest in her surroundings, and is slow in responding to questions and instructions. The visual fields are much contracted, but she gets about without difficulty. The pupils are dilated and very sluggish in reaction to light and on convergence. The fundi are normal. Conjugate movement of the eyes is defective. The upper limbs show some intention tremor, slight ataxia and weakness. The lower limbs are tremulous on voluntary movement; the tendon reflexes are all brisk; there is no abnormality in sensation, gait and superficial reflexes. The asthma and bronchitis have much abated while she has been in hospital, but the general condition has not changed.

Case of Amyotrophic Lateral Sclerosis.

By Dr. WILFRED HARRIS.

Mrs. K., aged 66. Two years ago had influenza and double pneumonia, and has never been well since. Has noticed gradually increasing weakness of her hands and all over, with excessive perspiration. No pain or numbness.

On examination she shows bilateral tendency to foot-drop and wrist-drop, suggestive of a polyneuritis. She cannot walk on her heels, but can do so on her toes. She cannot extend the hands and fingers properly, extension on the ulnar side being weaker. On clenching the fists there is noticeable marked paresis of the radial extensors of the wrist, while the ulnar extensors are normal, causing adduction of the wrists to the ulnar side, more especially of the right wrist. No weakness nor atrophy of intrinsic muscles of the hands, or of the arms or shoulders. Flexion of the fingers and wrists is normal. In the lower extremities there is no weakness of the thigh muscles, but there is weakness of the peronei, especially of the right leg, and marked weakness of the tibialis anticus on the right side, less on the left. All the paralysed muscles show corresponding diminution to electrical test, both to faradism and to galvanism. K.C.C. > A.C.C. Knee-jerks present; no ankle clonus. Bilateral extensor plantars. No sphincter weakness. No cranial nerve weakness.

Hyperidrosis in Syringomyelia.

By Dr. WILFRED HARRIS.

J. K., aged 47. Thirty years ago he fractured the inner condyle of the right humerus. Fifteen years ago he began to have pains like pins and needles in the right hand and arm. For a year or more he has noticed profuse sweating about the head and neck, principally on the right side, front and back of head, and on the left face; the colder the weather the more he sweats, and if he eats anything acid or pungent, or cheese, he says the right side of his face breaks out into a "fountain" of sweat. Constipation especially noticeable the last three years.

On testing him with a small meal of Gorgonzola cheese, I found the excessive sweating was not noticeable until ten to fifteen minutes afterwards. There is marked atrophy of the right hypothenar muscles and of the interossei, none of the thenar. There is analgesia of the right ulnar nerve area, and considerable hypertrophy of the right ulnar nerve just above the elbow for about $1\frac{1}{2}$ in. There are areas of analgesia and thermanæsthesia on the right second, third and fourth cervical areas, and on the chest and abdomen, especially on the left side down to the groin. Slight kypho-scoliosis. A year ago he says he burnt himself on the right palm unwittingly.

The knee-jerks are normal, and there are bilateral extensor plantars, with bilateral pes cavus. Cranial nerves normal.

Dr. KINNIER WILSON said that this case strongly suggested the diagnosis of chronic hypertrophic neuritis of Dejerine and Sottas. He said that it should be borne in mind that one at least of the original cases described by these observers was diagnosed as syringomyelia. In favour of the diagnosis of hypertrophic neuritis, he thought, were the apparent hypertrophy of the ulnar nerves on both sides and the bilateral pes cavus. A similar condition had been noticed in other recorded instances of the affection, and was not characteristic of syringomyelia.

Dr. WILFRED HARRIS (in reply) said that the enlarged condition of the right ulnar nerve was in his opinion due to the old fracture at the right elbow, the wasting of the muscles supplied by the ulnar nerve resulting from the chronic neuritis. The unconscious burn on the hand, the numerous areas of analgesia and thermanæsthesia and the paradoxical sweating were all points suggestive of a diagnosis of syringomyelia rather than of chronic hypertrophic neuritis.

Case of Poliomyelitis.

By Dr. WILFRED HARRIS.

J. W., aged 13, and his elder brother were both taken acutely ill two months ago at Brighton with headache, delirium and pains in back and legs. The elder brother rapidly became paralysed all over, first in the legs and then the arms, and died in three days. Lumbar puncture was negative, and no

autopsy was made. In the younger boy lumbar puncture is said to have yielded meningococci, the diagnosis of cerebrospinal meningitis having been made in both cases. On recovery from the acute illness the patient was found to have paralysis in both arms, the left being the worse, with some weakness in the right leg.

He has complete paralysis and wasting of both deltoids, and of the left biceps, supinator longus and radial extensors of the wrist. The right shoulder-joint is partially fixed by adhesions. There is no anæsthesia. The left foot is considerably smaller than the right, spastic in appearance with an extensor plantar reflex. The left hand is also slightly smaller than the right, this being presumably due to an infantile hemiplegia, possibly a birth palsy, as the mother knows of no acute illness in childhood which could have affected him thus; but his birth was difficult and prolonged, and she first noticed him to limp slightly at the age of 3.

Case of an Adult Cretin.

By Dr. A. FEILING.

Patient, a female, F. H., aged 29. Height 50½ in. Weight 5 st. 11¼ lb.

Nothing known of the father. Mother is alive and well. Two brothers alive and well. No other member of the family affected in the same way.

The patient was born in London and, except for a few years' residence in Warwickshire, has always lived here. She states that she has always been very small. Went to school and reached Standard VII.

Her appearance is that of a cretin. The mental state, however, is quite normal.

Case of Total Unilateral Ophthalmoplegia with Foot-drop.

By Dr. A. FEILING.

Patient, a male, aged 58, began to suffer six months ago from headaches; three months ago he felt ill and tired and about two months ago had an attack of violent vomiting. After this it was noted that the left eyelid drooped. Examination at this time showed a complete left ophthalmoplegia with some degree of proptosis.

Admitted to hospital on November 2, 1923. A total left ophthalmoplegia affecting both internal and external eye muscles. No other abnormal signs found. Wassermann reaction in the blood and cerebro-spinal fluid negative; no abnormalities in the cerebro-spinal fluid. Examination of the throat and nose quite negative: X-ray examination of the skull negative.

Whilst in hospital he gradually developed weakness of the power of dorsi-flexion of the right foot. This gradually progressed to a complete foot-drop. There is wasting of the anterior tibial and peroneal muscles; no loss of sensation has been present.

At no time has any other abnormal sign been found.

Case of Amyotonia Congenita.

Shown by Dr. A. FEILING, M.D. (for Mr. R. C. ELMSLIE).

Female child, aged 4. No history of any similar disease in the family. Mother states that child was quite normal till the age of 15 months when she became weak. Weakness has become progressively worse. At one time the child could crawl and stand but she has never walked.

Previous history.—Chicken-pox and whooping-cough in infancy. At age of 15 months fell on her chin and was insensible for two hours.

She is now quite unable to stand or crawl, or to raise herself up from the recumbent position. When placed in a sitting posture can remain there. Mental state satisfactory. Pupils, cranial nerves and upper extremities normal. Flaccid weakness of all muscles of trunk, abdomen and lower extremities. Well marked hypotonia. Loss of tendon reflexes and of the superficial reflexes in the lower limbs.

Dr. FEILING said that he showed this case chiefly from the point of view of diagnosis. Was it one of amyotonia congenita or one of the progressive spinal paralysis of Werdnig and Hoffmann? Personally he confessed to a great difficulty in making the differential diagnosis.

Dr. COLLIER said that the case was in every way a typical one of the amyotonia congenita of Oppenheim, and differed entirely from what he recognized as the Werdnig-Hoffmann disease. He had seen several examples of the latter disease, and of these two had been examined pathologically and had proved to be cases of progressive degeneration of spinal neurones. He thought that Knud Krabbes' review had confused the issue in that he had included cases of Oppenheim's disease in his selected list of cases of Werdnig-Hoffmann disease, notably some of the cases recorded by Dr. Wilson and himself.

Cases of Progressive Lenticular Degeneration and Hepatic Cirrhosis.

By Dr. STANLEY BARNES (Birmingham).

These three children are the offspring of parents both of whom appear to be healthy. There is no history of nervous disease or of cirrhosis of the liver in the family of either parent. The family (of whom three members are shown) consists of eight children, whose ages range from 16 years to 1 year old. All the children have been examined; two only (Cases 1 and 2) show signs of nervous disease, whilst in four of them there is more or less indication of liver disease. The three eldest children show neither nervous nor hepatic disease.

Case 1.—Phœbe B., aged 11. In February, 1920, she had a febrile illness with jaundice. There was no œdema or ascites. Since then she has had occasional attacks of vomiting, occasionally hæmatemesis.

In February, 1922, her tonsils and adenoids were removed as she had an offensive discharge from the nose. The attacks of vomiting continued, accompanied by feverishness; she was hysterical on occasions and would cry out for no reason.

The stiffness of the limbs came on during 1922, and with this there was increasing dysarthria and excessive salivation with constant dribbling.

She was admitted to the General Hospital, Birmingham, July 20, 1923. She was an emotional child of moderate intelligence. The mouth was kept half open and the face had a very vacant expression. The smile was stiff and slow.

All the muscles appeared to be unusually rigid, particularly those of the right side of the body. On passive movement there was always more resistance than the normal, and this was more marked in the arms than the legs. Any attempt at gripping with the right hand, after producing a powerful action, was of such a tonic type that relaxation was only possible after a few seconds of effort. Both arms, but particularly the right, were extended in decerebrate position; the legs, and particularly the right, tended to adopt the equino-varus position. Although no tremors were present, all action of face, arm and leg was accompanied by athetoid movement. Speech was slow, slurred and monotonous, and has more recently become almost unintelligible; and there have been and are constant difficulty with mastication and persistent drooling.

At various times the liver has been felt to be hard and is palpable at a distance of about 1 in. below the costal margin. Sometimes the liver has been felt to be considerably larger, and at others smaller; but in all cases the consistence has suggested cirrhosis; the spleen has usually been palpable. A lævulose test for liver function showed deficiency; the Wassermann reaction was negative.

Case 2.—Frederick B., aged 10. In December, 1919, he had frequent attacks of vomiting with hæmatemesis on one occasion. On December 25, 1919, it was noticed he was jaundiced and a week or so later he developed ascites and œdema of the legs. He was treated at the Children's Hospital for cirrhosis of the liver, and the abdomen was tapped and four pints of fluid removed. The liver at this time was reported enlarged and nodular, the lower border being 1 in. below the costal margin. The spleen was not palpable. After leaving the Children's Hospital he had whooping-cough and nervous debility. He became stupid, his memory bad, and he had no inclination to work or play. There were occasional attacks of drowsiness.

In February, 1922, he had a febrile illness and following this the stiffness of the limbs was noticed, with dysarthria and constant dribbling. He suffered with diarrhœa and attacks of vomiting. He was admitted to the General Hospital in November, 1922. At this time there was rigidity of the right arm and both legs. On gripping with the right hand the grip could not be loosened without the assistance of the left hand. On standing, the right leg was held slightly adducted, the knee extended and the foot internally rotated. The right arm was held in the decerebrate position. Athetoid movements of the right arm were present. The expression was fatuous and vacant, he was highly emotional and the speech was slow, drawling, monotonous and blurred. There was constant dribbling of excessive saliva.

Examination of the nervous system showed no evidence of pyramidal disease and no ocular damage. A lævulose test indicated liver deficiency. The Wassermann test was negative.

He was again admitted to hospital in March, 1923, when further degeneration had occurred. The expression was one of complete vacuity, the mouth being held nearly half open, with constant dribbling. The speech had become almost incoherent and the lesion was now bilateral. There were athetoid movements of both arms. There was marked rigidity of the arms, but the right arm was less rigid than previously. There were no tremors. The legs showed an increased amount of rigidity, the right foot being held in a position of equino-varus. The liver was not palpable below the costal margin at this period.

Case 3.—Elsie B., aged 8. This child was examined in July, 1923, when it was found that the liver border was hard and palpable, 1½ in. below the costal margin. There were no symptoms at that time, but in August she began to have attacks of vomiting, which recurred every four weeks. The vomit was intensely yellow, sour and acid.

On December 24, 1923, she complained of abdominal pain and shivering, and on December 25 it was noticed her eyes were jaundiced. The abdominal pain continued, there was vomiting, and the jaundice became more marked. On December 26 it was noticed that the abdomen was swollen, and she complained that her boots were too tight. She also complained of pains in the right side of the neck and buzzing in the ears. There had been several attacks of vomiting, and on Saturday, December 29, the mother said she noticed an inflammation around the umbilicus.

She was admitted to hospital on January 2, 1924: at that time she was slightly jaundiced. She seems an intelligent child, and shows no rigidity of face or limbs. On examination of the abdomen there is seen to be a marked ascites. The lower border of the spleen can be felt 1½ in. below the costal margin. The liver has an upper border found by percussion at the seventh rib, and the lower border is hard and extends 1 in. below the costal margin. The urine contains a cloud of albumin and bile pigment.

The nervous system shows nothing abnormal.

Dr. KINNIER WILSON said the Section was very greatly indebted to Dr. Stanley Barnes for the trouble he had taken in bringing these extremely interesting cases to London. He agreed that the clinical picture was quite consonant with that of progressive lenticular degeneration. He pointed out several features of clinical interest in connection with the cases, and emphasized the great importance of Case 3. The facts in connection with this latter case could clearly be taken to indicate that the liver affection preceded the lenticular degeneration. Its ætiological value, therefore, was very considerable; in fact, it might also be regarded as the "link" that had hitherto been "missing."

He expressed the hope that a full report of the cases would be published in due course.

Case of Muscular Atrophy, resembling the Peroneal Type of Charcot, Marie and Tooth, in a Woman, commencing at the age of 46.

By Dr. GEORGE RIDDOCH.

Alice M., aged 57, married. Eleven years ago she first noticed that her hands trembled when she used them. Three years ago her legs became weak, and she dragged her feet in walking. About the same time articulation began to be tremulous. From the beginning she has had no pain apart from occasional headaches during the past four or five months. Her disability has been gradually and steadily progressive.

At the age of 20 she had scarlet fever, but otherwise her health has been excellent before the onset of her present trouble. Her consumption of alcohol is moderate.

She married at 28, and has two daughters, aged 30 and 28 respectively, who have always been healthy. There were no other pregnancies. Her husband died eleven years ago of cirrhosis of the liver.

Her father, who is 82, became paralysed two or three years ago. Her mother died at the age of 39 of heart disease. Her only brother and sister are alive and healthy.

She is a well-nourished woman of fair intelligence, but poor education. Speech is normal, but articulation is tremulous. Hearing and vision good, discs and fundi clear.

Pupils and cranial nerves are normal, except that when she is speaking the lower part of her face is sometimes tremulous. Voluntary power in her upper limbs at the shoulders and elbows is excellent. There is weakness and wasting, more on the left than on the right side, of the muscles of her forearms and hands, especially of the flexors of her wrists and fingers and of the thenar and hypothenar muscles. In her lower limbs weakness and wasting are confined to the muscles below her knees, and the dorsiflexors of the feet and toes and the peronei are specially affected, being completely paralysed on the left side. There is no muscular fibrillation. Supinator, knee and ankle jerks are absent on both sides. Abdominal reflexes are present and equal on the two sides and the plantar responses are flexor.

Sensibility to light touch is impaired in the peripheral parts of both lower limbs, left more than right, and that to pin-prick is diminished in her left foot only. Postural sensibility is defective in the fingers of both hands and, to a greater extent, in the toes, especially of her left foot. Recognition of the vibrations of a tuning-fork (C = 128) on her hands and lower limbs below the knees is impaired. Deep pressure pain is abolished in her calves.

There has been no sphincter trouble.

Both feet are a little swollen on their dorsal aspects. The Wassermann reaction is negative in her blood and spinal fluid, the latter showing no increase in protein or cells and giving a negative colloidal gold test.

Case of Juvenile Tabes with Nystagmus, Dysarthria, and Head-rolling.
By Dr. GEORGE RIDDOCH.

DORIS F., aged 20, unmarried. Five years ago she began to walk unsteadily, especially in the dark, and her left shoulder drooped. Her ataxia got steadily worse, and a year later she developed dysarthria and an involuntary lateral tremor of her head. She also began to drop things out of her hands if she failed to "keep an eye" on them. Recently she has tended to gasp for breath on slight exertion.

At the age of 9 years she had an illness that was diagnosed as "brain fever," in which she was delirious.

Her father, mother, two brothers and one sister are alive and well. One brother died of peritonitis when a year old.

She is a bright, intelligent girl. Speech is normal, but there is definite dysarthria. Hearing and vision are good. Discs and fundi clear. Pupils moderately dilated; right slightly larger than left; their outlines are a little irregular; the reaction to light is sluggish in the right and absent in the left; the reaction on convergence is good. Ocular movements are full; there is no diplopia, strabismus, or ptosis, but nystagmus is evoked on lateral fixation. Sensibility to pin-prick is slightly diminished on the left side of her face. The other cranial nerves are normal.

There is no weakness, wasting, or dystonia of her upper and lower limbs. With her eyes shut her upper limbs, especially the left, are slightly ataxic. She has an unsteady gait and sways on attempting to stand with her feet together.

Supinator, knee, and ankle jerks are absent; abdominal reflexes are present and equal on the two sides and her plantar responses are flexor.

Sensibility to light touch and pin-prick is unimpaired in her limbs and trunk, and she has no pain. Postural sensibility is defective in the fingers of her left hand and the toes of her right foot. There is diminished appreciation of the vibrations of a tuning-fork (C = 128) in the fingers of her left hand and in her left foot. Bladder control is perfect. Her fingers are blue, but to her they do not feel cold. Her heart, lungs and abdomen show no abnormality. The Wassermann reaction is negative in her blood and positive in her spinal fluid. The spinal fluid is normal in regard to albumin content, cells, and colloidal gold test.

Dr. KINNIER WILSON said that this patient had been under his care at the National Hospital a year or two ago, and that the diagnosis then made was Friedreich's disease. Routine tests had been employed in the blood and spinal fluid, and they were completely negative. In his opinion there was no symptom that the patient showed which was incompatible with the diagnosis of Friedreich's disease. He felt very doubtful as to the likelihood of a Wassermann test being positive in the spinal fluid when the albumin content, cell content, and colloidal gold reaction were all negative.

Clinical Meeting at the National Hospital for the Paralysed and Epileptic, Queen Square, on March 13, 1924.

A Form of Involuntary Movement of One Arm.

By Dr. W. ALDREN TURNER. (Shown by Dr. CRITCHLEY.)

A. M., male, aged 34, developed in 1918 a febrile attack characterized by "pains all over," headache and malaise. He was in bed four days and returned to duty in a fortnight. There were no ocular symptoms, lethargy or delirium. Two years ago he became troubled with an involuntary eversion movement of the right hand, which occurred when he attempted to write. This condition, which was diagnosed as "writer's cramp" cleared up in six months. Last July he noticed that he was unable to hold out a newspaper steadily owing to an involuntary drawing-in of the left arm. This movement has now increased in strength, so that it occurs whenever the arm is in any position other than flexed and pronated across the chest.

The patient's mental and physical condition is normal, and there is no speech defect; he is left-handed for many actions.

Examination of the nervous system reveals no abnormality in the cranial nerves other than a greater emotional movement of the right side of the face. The left masseter muscle feels wasted, probably due to arthritis of the left jaw-joint.

All voluntary movements are present and full. Tone is normal in all limbs but there is a slight cog-wheel rigidity in the periphery of the left arm, more marked in the extensors than in the flexors. There are no involuntary movements in the leg, trunk, face or right arm, but a slow characteristic movement occurs in the left arm when it is placed in any position other than pronated, flexed and abducted across the chest. The movement is best seen when the arm is made to hang extended and supinated by the side. In this position three distinct consecutive movements take place; first, pronation of forearm with internal rotation at the shoulder; then flexion at the elbow-joint together with abduction of the upper arm; and finally further internal rotation of the arm, pressing the hand on to the chest. The whole cycle takes twenty-four seconds to complete. There is no gross accompanying alteration in tone, and the very slightest touch is sufficient to check the movement. If the check is maintained, the biceps, triceps and deltoid muscles contract strongly against the resistance, and the triceps become prominent. The patient can, by exercising considerable effort, temporarily overcome the movement, but the spasm continues as soon as the effort is withdrawn. The movement is unaffected by fatigue or by lumbar puncture. It ceases during sleep, the arm taking up the position of rest.

There are no objective sensory changes, but the patient often complains of a dull pain deep in the arm. The left arm-jerks are brisker than the right, otherwise the reflexes are normal. When walking there is no loss of associated

movements, but the left arm is held abducted from the side, slightly flexed at the elbow with the forearm hyperpronated and the back of the hand resting behind the left hip.

The blood Wassermann reaction, the cerebrospinal fluid, the blood-count, and the urine are normal. There is no change in the electrical reaction of the left arm muscles. Two hepatic efficiency tests were performed; viz., the hæmoclastic crisis test and the lævulose curve test. In both cases an abnormal reaction was obtained.

Case of Progressive Muscular Atrophy following Poliomyelitis.

By Dr. JAMES COLLIER.

F. H., male, aged 14. At age of 2 years and 4 months had an acute febrile illness in which he lost the power of the legs. This was followed by wasting in the legs. No pain was associated with this illness.

During the following years he gradually became weaker and developed marked deformities.

At the age of 10 years his arm suddenly became much weaker (there was no febrile illness in association with this).

On examination marked weakness of neck muscles, wasting of arms and of legs, in which the only movement left is flexion of the left leg.

No fibrillation observed. Reflexes absent. Wassermann reaction negative.

Case of Progressive Muscular Atrophy (?) occurring Forty-two Years after Infantile Paralysis.

By Dr. W. J. ADIE.

E. W., female, aged 42. At age of 6 to 12 months she had convulsions while teething, followed by paralysis of the left leg. Ten or twelve weeks later there was gradual loss of power in the right leg. In September, 1923, at age of 42, gradual loss of power in the left hand began.

On examination there was wasting and fibrillation in both thenar and hypothenar eminences and in both triceps muscles. The arm-jerks are brisk and there is no sensory loss.

X-rays showed enlargement of both transverse processes of the seventh cervical vertebra.

She has used crutches for thirty-seven years.

Dr. CARMICHAEL said that the onset of symptoms of progressive muscular atrophy after an attack of poliomyelitis is so common that it cannot be regarded as a coincidence. On looking through the literature he had found that the symptoms of progressive muscular atrophy have been described as occurring at periods of from seven to fifty years after an attack of poliomyelitis. Two theories of the pathogenesis of the progressive muscular atrophy may be put forward: that a latent infection persists, or that owing to the injury they received the motor cells may be more vulnerable to disease in later life.

Case showing Spasm of the Muscles of the Face.

By Dr. JAMES COLLIER.

E. G., male, aged 44. In 1920 patient first had an epileptic seizure. Up till examination on February 17, 1923, he has had a series of twenty such fits. There is no weakness of either side, but slight difficulty in speech after each attack.

On examination.—Well-built man, who is unduly emotional, laughing and crying readily. Cerebration is slow and intelligence below average. Visual acuity, right, 6/12, left 6/18. Pupils show only the slightest response to light; fundi show vascular changes. His face is expressionless, the lower half of the face is in constant changing spasm. Movement of limbs is slow, power good, no tremor. All reflexes are present, plantar reflexes are flexor in type, and no sensory disturbance can be made out. Blood-pressure 246 mm. Hg; a trace of albumin is present in the urine.

Since admission periods of sub-coma lasting two to three days have occurred.

Dr. COLLIER, commenting on the case, pointed out that the occurrence of epileptiform seizures, progressive mental degeneration and the periods of sub-coma to which the patient is subject, all indicate an extensive or diffuse involvement of the cerebral cortex. In his opinion the symptoms must be attributed to lesions of the pyramidal tracts; such constantly changing spasm as is present in the lower part of the man's face never, in his experience, occurs as a result of disease of the brain-stem, except, perhaps, when the facial nuclei are involved.

Case of Syphilitic Amyotrophy (? Congenital Lues).

By Dr. T. GRAINGER STEWART. (Shown by Dr. E. A. CARMICHAEL.)

W. B., male, aged 49. Complains of weakness of legs with paræsthesia of four years' duration, commencing in the right foot. No bladder trouble, no eye trouble. When seen ten weeks ago the muscles of the limbs and trunk showed fibrillation.

On admission he was found to have disseminated choroiditis; no nystagmus, pupils react well. Motor power in arms fairly good. No wasting. Fibrillation in muscles of shoulder-girdle. No intention tremor. Unable to sit up without aid. Legs both weak. Right calf and thigh smaller than left; no fibrillation. Heel-knee and toe-finger tests well performed. Abdominal reflexes present, deep reflexes very brisk. Sphincters healthy. Sense of position slightly defective in both legs. Cerebro-spinal fluid on two occasions showed moderate lymphocytosis and Lange curve of paretic type. The Wassermann reaction was negative in both blood and cerebro-spinal fluid, but the patient has improved under mercurial treatment.

Case of Acromegaly and Syringomyelia.

By Dr. C. M. HINDS HOWELL. (Shown by Dr. CRITCHLEY.)

R. M., female, aged 38. Admitted for headaches and painless burns on hands.

Typical acromegalic deformities. Concentric diminution of both fields of vision. Wasting of hands. X-rays showed flattening of the sella turcica.

May, 1921: Cerebral decompression performed.

February, 1924: A second operation in which a pituitary cyst was tapped. This has been followed by complete relief from the headache.

A Case of Parkinsonian Syndrome with Argyll Robertson Pupils and Positive Wassermann Reaction. Disappearance of Tremor after Hemiplegia.

By Dr. S. A. KINNIER WILSON.

J. B., male, aged 67. For eight years has had lightning pains; three years stiff legs; two years tremor in arms and legs.

In January, 1922, showed on examination: Parkinsonian syndrome, weakness of right third nerve, Argyll-Robertson pupils, typical diminution to painful stimuli over the chest and arms.

Tendon reflexes exaggerated, left plantar reflex of extensor type. Wassermann reaction positive in blood and cerebro-spinal fluid.

He gradually became worse till 1924, when tremor became increasingly violent. On February 19 he became suddenly unconscious, and on recovery twenty-four hours later he had right hemiplegia, dysarthria and aphasia, but no tremor.

On March 3, 1924, examination showed right hemiplegia with double extensor plantar reflex. Wassermann reaction strongly positive in blood and cerebro-spinal fluid. Rigidity of trunk and limbs, but no tremor.

Dr. SYMONDS pointed out that a typical tremor of the right arm could be obtained, though the oscillations were very small in range, if the patient made an attempt to grasp with this hand.

Dr. MACBRIDE, replying to Dr. Collier's inquiry as to the probable position of the lesion which produced the hemiplegia, suggested that it lay in the lower portion of the internal capsule. He admitted that though the spontaneous tremor had disappeared, some could be elicited by such devices as Dr. Symonds had pointed out.

Dr. GORDON HOLMES stated that in his experience it was the rule to find Parkinsonian tremor due to paralysis agitans, to local lesions of the mid-brain, and that which occurs as a sequel to lethargic encephalitis, disappear when any severe degree of weakness, the result of injury of the pyramidal tracts, develops.

A Very Slow-growing Endothelioma removed by Operation.

By Dr. S. A. KINNIER WILSON.

J. S., male, 25 years. In 1913 was struck on the right side of the head by a taxi-cab.

In 1914 tingling began in the left hand. Later in the same year he underwent a right-sided mastoid operation.

In May, 1914, twitching of the left hand spread up the arm, involving the left side of the face, and then spread into the legs, after which he became unconscious. On recovering consciousness he was paralysed in the left arm and leg for about an hour. Attacks of a similar nature recurred at varying intervals. Between attacks there was paræsthesia in the left upper limb.

The optic discs showed a suspicion of early papillœdema in 1920, but were not definitely pathological till 1923.

1923: Definite slight weakness in left arm with defective sensation; left plantar reflex of extensor type.

In November and December, 1923, endothelioma removed by operations in two stages.

Dr. GREENFIELD referred to certain points of interest in this case. In the first place a radiographic examination revealed no thickening or other disease of the bone in the neighbourhood of the tumour, although this was extensively involved and enormously thickened. This was due to the fact that no excess of calcium salts was deposited in the portion of the tumour which infiltrated the bone. Histological examination of the tumour gave interesting results; its central portion consisted mainly of fibrous tissue, but its edges were more cellular, and in one place it had extended through the pia-arachnoid and infiltrated a small portion of the brain which was removed with it.

Case of Central Gliosis of Spinal Cord (?).

By Dr. A. KINNIER WILSON. (Shown by Dr. MACBRIDE.)

Male, aged 13. For the last two years has had gradually oncoming weakness in the right lower limb. This involved the left leg about a year ago, since when he has been unable to walk. Over two years ago he had an "itching" sensation in right upper limb, and then weakness gradually came on in it. There has been incontinence of urine.

On examination.—Unilateral sweating on right side of face; nystagmus; weakness and wasting of right upper limb; paresis with spasticity in lower limb. Diminution to pin-prick, heat and cold from 7 C. to 11 D.: loss from 1 D. to 10 D. Tactile hypoæsthesia over this area; passive movement in legs defective.

Reflexes.—Arm-jerks absent on both sides. Knee-jerks and ankle-jerks exaggerated. Both plantars of extensor type. The spine shows no abnormality.

Dr. COLLIER inquired if operative treatment had been considered in this case. In a similar case under his care a laminectomy had been performed, and

the cord was incised and a portion of the tumour was removed. The result was extremely satisfactory as the boy regained power in his legs and was able to walk out of the hospital; only one of his arms remained weak. It was extraordinary that no additional damage to the cord resulted from its incision.

Case of Pontine Lesion of Traumatic Origin with Alternate Paralysis (Millard-Gubler Syndrome).

By Dr. C. WORSTER-DROUGHT.

P. L., aged 35, in 1916 fell heavily from a motor lorry, his head and upper part of back striking the ground. The impact rendered him dazed and giddy, and subsequently he vomited. On the following day he complained of weakness in the right arm and leg, difficulty in speaking, and noticed that the left side of his face was "twisted"; some urinary incontinence also developed. His condition has changed very little since the accident.

Present condition.—Cranial nerves: pupils equal and normal in reaction; nebula right cornea. Optic discs normal. Fine rotatory nystagmus, more to right than left; ocular muscles otherwise normal. Left facial weakness of lower neurone type. Some degree of nerve deafness left ear. Tongue deviates slightly to right on protrusion.

Sensation.—Impairment of light touch, pain, and thermal stimuli over left side of face and right side of trunk including right arm and leg.

Motor functions and reflexes.—Stands with slight deviation towards the right and walks with difficulty, dragging right leg. Right arm and leg spastic with considerable weakness. No appreciable difference in arm-jerks. Abdominal reflexes: right absent, left normal. Knee and ankle jerks: right brisker than left. Right ankle clonus. Plantar reflexes: right extensor, left flexor.

Heart, lungs and other symptoms normal. Wassermann reaction in blood, negative.

Dr. WORSTER-DROUGHT said that the chief interest in the case was the nature of the lesion. It seemed to him that, if the man's history were correct, it was most probably of vascular origin.

Dr. FEILING said the patient had been under his care three years ago. He was then in much the same state as he is now, but he believed that at that time he had also weakness of one external rectus muscle. The history the patient gave was, however, quite different to that furnished by Dr. Worster-Drought, as he then stated the symptoms had come on gradually after the accident. He was then inclined to regard the case as one of disseminated sclerosis and he still inclined to this diagnosis.

Dr. COLLIER pointed out that the man had a spasm of one side of his face; this, in his opinion, never occurs in disseminated sclerosis, and is never due to an intramedullary lesion of the brain-stem.

Mr. LESLIE PATON said that if there were no external rectus paresis the term Miller-Gubler syndrome was inapplicable.

Dr. SYMONDS said that in his opinion there were very strong arguments against the diagnosis of disseminated sclerosis. In the first place all the symptoms could be explained by a single local lesion of the brain-stem, in the second it had remained practically unaltered for a considerable time. It seemed to him most probable that the man had a fracture of the base of the skull and a hæmorrhage into the pons.

Dr. GORDON HOLMES had seen the case some time ago and then obtained a different history of the mode of onset of the condition. As far as he remembered the man then admitted that the symptoms had developed gradually. The patient is a war pensioner and his claim to a pension is now being disputed, so it looked as though he were making as strong a case as possible for compensation, and therefore attempting to connect his symptoms as closely as possible with the accident.

Case of Bilateral Facial Paralysis apparently of Traumatic Origin.

By Dr. C. WORSTER-DROUGHT.

J. J. D., male, aged 27, while lying in a dressing station in France during 1918, suffering from the effects of "gassing," was involved in a shell explosion. He lost consciousness, and does not remember anything further until he regained consciousness in England, and noticed that he constantly dribbled, and that his face felt stiff. His facial condition has remained unaltered.

Present condition.—There is a bilateral facial paralysis; his forehead is immobile, and he cannot close his eyes. The only movement present is at the angles of the mouth: the left side shows a little more movement than the right, but on both sides it is very slight. He is unable to pronounce labials. To faradism ordinary reactions are absent, excepting that a very sluggish reaction can be obtained in levator labii superioris, risorius and depressor anguli oris on each side. All other cranial nerves are normal. Sensation, reflexes, &c., also show no abnormality.

Dr. COLLIER said that the most interesting feature in this case was the extraordinary distribution of the palsy; the only movement of his face which the patient is able to perform is retraction of the angle of the mouth, but he also moves his ears quite well. This irregular distribution of the affection excludes the possibility of it being due to a lesion of the trunk of the nerve, and makes an affection of the facial nuclei more probable.

Sir PURVES STEWART examined taste with the galvanic current, and Mr. Sydney Scott by the ordinary test solutions, and they both found it intact. They regarded the paresis as being undoubtedly due to nuclear lesions, probably bilateral hæmorrhages as the result of the explosion.

Case for Diagnosis.

By Dr. C. WORSTER-DROUGHT.

W. F., aged 32, has complained of gradual weakness and wasting of the left leg, which began in 1917.

Physical signs.—Pupils equal and all reactions normal. Slight nystagmus

on lateral deviation of eyes occasionally observed. Fundi normal. Slight degree of facial atrophy with slight facial tremor on showing teeth. Arm-jerks usually equal, no paresis and no incoördination of arms; no intention tremor. Abdominal reflexes: left absent, right very slight. General wasting of left leg, especially of foot. Paresis of dorsiflexors of left foot and peronei. Tibialis anticus and peronei react sluggishly to faradism. Left knee and ankle jerks brisker than right. Left patellar and ankle clonus. Plantar reflexes, right flexor, left usually indefinite or sluggish extensor.

Sensation.—There is loss of cutaneous sensibility to all stimuli over left leg, the area extending to half way up the thigh. Sensation is also somewhat diminished but not absent over the left half of the trunk and left arm. The toes are frequently cyanosed.

The blood yields a negative Wassermann reaction. Cerebro-spinal fluid: two cells per c.mm., protein 0·02 per cent. Wassermann reaction negative.

Case of Cerebro-Macular Degeneration.

By Dr. J. S. RISIEN RUSSELL.

R. B., female, aged 8. July 25, 1921, the child screamed out; on the following morning the mother found that she was unable to walk. No previous illness and abnormality had been noticed. On November 6 she had a fit, since then she had deteriorated mentally. Parents are alive and well. One boy, aged 2 years, quite well. No deaths and no miscarriages. Child is illegitimate.

On examination the child exhibits an unhealthy mouth; she is mentally backward for her age, and this makes the physical examination difficult. Eye-sight fair, fundi show an opaque appearance of both discs and retinal pigmentary changes, especially at the macula.

The reflexes are brisk, the plantars are doubtfully extensor in type, and she is doubly incontinent.

Two Cases of Cerebro-Macular Degeneration.

By Dr. W. J. ADIE.

J. R., male, aged 11. Symptoms commenced at age of 7½ years. Marked mental deterioration, blindness, occasional epileptiform convulsions and frequent jactitations of head and neck. Tendon reflexes exaggerated. Plantar reflexes of extensor type.

R. R., male, aged 8. Symptoms started a few months ago, with impairment of vision and tremblings and occasional fits. Slight mental deterioration. Tendon reflexes exaggerated. Plantar reflexes of extensor type.

Mr. LESLIE PATON, in discussing these cases which he had the opportunity of observing, pointed out that the latter two cases belonged to a family in which a sister was also affected. It was of these he particularly wished to speak. The affected members are a boy, aged 8 years; a girl, aged 10; and the eldest boy, aged 11. In all three, the changes began to manifest themselves

at secondary dentition. All three have been under observation for some considerable time, the youngest boy having nothing wrong with him when we first saw him. In his case, the maculæ and retinæ generally were quite normal till last July. Then he had a fit, and soon after this we observed the first and earliest changes in his macular regions, small white areas at the maculæ with reddish rings round them. So slight was the change that if he had not been under observation we might have regarded it as a normal, glistening fovea, of the bull's-eye lamp reflex character. The change was a little more marked in the left eye than in the right.

The sister shows the second stage in the development of the macular disease; the white area, with the reddish ring round it, is very much more defined and the perimacular retina shows a streaky whitish appearance of degeneration. The disc is atrophic and the vessels diminished in calibre.

The elder brother shows a still further stage in the degenerative process, the atrophy of the macula being complete, and appearing as a much larger white area, speckled over with black pigment; the peri-muscular area presents the same streaky white appearance, and the whole peripheral retina is atrophic, with pigmentary changes resembling those of retinitis pigmentosa. The disc is white and the vessels are reduced to tiny threads.

The cerebral signs show similar progression from the youngest to the eldest. In the youngest boy there is, as yet, very little spasticity, but during the fits spastic conditions are manifest, and he has the slight jerky movements; the others show these in greater degree. The elder boy was very spastic in the earlier stages but the spasticity seems not to be quite so marked now. He has no control of his movements in walking and cannot stand up. He is completely incontinent. The girl shows the intermediate stage, with marked spasticity and jactitation. All the deep reflexes are exaggerated.

Clinically, this condition, commencing usually about 6 to 9 years of age, is closely allied to Tay's amaurotic family idiocy. In amaurotic family idiocy, the disease most characteristically affects Jewish children. It commences in infancy and proceeds rapidly to complete cerebral degeneration, with macular degeneration, and the children usually die before reaching the age of 2 years. It has been met with at least in one case in a child of purely Gentile parentage, reported by Dr. Harris about the year 1910. In amaurotic family idiocy the whole progress of the disease is very much more rapid than it is in these cerebro-macular cases in which it commences in later childhood.

There is a third type, which I feel inclined to associate with the other two, commencing usually about puberty. In this, the macular and retinal changes are almost exactly like those found in the cerebro-macular degeneration type, but the cerebral symptoms are only very slight. I have recently had under observation two or three cases of this kind. The children in whom it occurs are usually intellectually backward, many of them at the age of 13 or 14, when the blindness commences, have only reached the first standard at school. In some of them there does not seem to be any intellectual deficiency, but with the progress of the retinal degeneration some signs of cerebral defect

develop. Of one boy, in whom the macular condition was very marked, his parents remarked that he had changed in temperament, becoming very moody and irritable and liable to explosions of violent temper.

Clinically, then, I should say that there are three definite types, one commencing in infancy, very rapid in its progress, with very rapidly developing degenerative changes in the retinæ, cerebellum and central nervous system generally. The second type, the Batten type, coming on after secondary dentition, develop more slowly, with a clinical history often extending over seven or eight years, but in which the final stages show the same complete degeneration of the central nervous system and in the retinæ as the infantile type. Then there is the third type, not so definitely allied to the other two, in which the cerebral symptoms are very slightly marked but the retinal changes are similar to those found in the other two types.

The pathological changes found in the cells of the central nervous system seem to consist in lipoid infiltration, mainly affecting the vegetative portion, as distinct from the neuro-fibrillar portion of the larger cells. The Nissl granules get crowded into the one portion of the cell as the lipoid material develops, and the neuro-fibrils get pushed to the sides.

Dr. GREENFIELD referred to the pathological changes characteristic of these different types of disease, and especially to the changes he found in the nervous system in the case of a boy subject to the juvenile type of the disease who had died recently. These changes will be described more fully later.

Mnemic Psychology. By RICHARD SEMON. Translated from the German by Bella Duffy. With an Introduction by Vernon Lee. Pp. 343. London: Allen and Unwin. 1923.

The author of this book was born in 1859, and ended his life by his own hand in December, 1918. As a Privat Docent, attached to the Anatomical Department in Jena, he came under the influence of Haeckel, and made his reputation by a journey to Australia and the Malay Archipelago, undertaken for the purposes of zoological research. On his return he settled down as a teacher in the University, and had it not been for certain personal and domestic difficulties, which cut short his anatomical career, he would probably have been known to fame as a zoologist and a brilliant teacher.

Forced to retire into private life, his mind was turned into new channels. In 1871, Ewald Hering delivered his address on "Memory as a Function of Organic Matter," which has become famous to English readers through the somewhat fantastic speculations of Samuel Butler. Hering suggested that as individual memory was due to the traces left on the nervous system by events in the past, so hereditary transmission was due to similar dispositions carried over from parent to offspring. Semon saw that a great deal more than "Memory" was involved in the continuity of biological processes underlying an hereditary function, habit or instinct, and he therefore adopted the word "Mneme" for the "principle of conservation in the mutability of all organic happenings."

This conception he developed into a wide philosophic system, embracing not only biological processes of all kinds, but also those of the mind. These principles he enunciated in "Mneme,"[1] first published in 1904; a book which ran through many editions and has had a profound effect on Continental thought. Semon's ideas have recently been brought to the notice of workers in this country by the wide use to which they have been put by Bertrand Russell in his "Analysis of Mind" (1921).

The immediate result of a stimulus upon living matter is to produce excitations. This is followed by definite effects which may be expressed in motor or plastic vital manifestations, or as metabolic phenomena; but the consequences of stimulation may also appear as a sensation, that is, a form of mental activity which can be appreciated introspectively. Whatever the form assumed by the response, it leaves behind it traces of its action, which

[1] Translated by Louis Simon and published by Allen and Unwin in 1921.

Semon called an "Engram." This is a durable but latent change, a material modification of organic substance, but Semon wisely refused to discuss the phenomena in terms based on hypothetical atomic changes. He contends that engrams are stored in the cerebral cortex, not in special nerve cells like papers in a drawer, but in the form of a tendency to action. This he calls "topogenous" localization. He also insists that, since the serial order in time of their deposition has a fundamental effect on the manner in which engrams can be brought into action, there must be another form of localization, which he calls "chronogenous." This conception plays a leading rôle in the work of von Monakow and is familiar to all students of his work on "Lokalisation."

The original presentation of Semon's views dealt with "mnemic excitations" in general; he laid down the laws under which they acted and their various biological manifestations in the life of plants and animals. But it was obvious that if these principles had any validity they must apply equally to psychology; in fact, they form the very basis of the life of the mind. This aspect of his theory Semon set out in "Mnemische Empfindungen," which appeared in 1909 and is the original of this translation. His first book was full of matter which, like the question of the transmission of acquired characteristics, is still under debate; but the present work is a straightforward statement of psychological phenomena in terms of the mnemic theory and is confined to a consideration of those responses which take the form of sensations. Moreover, it deals with the individual life of the organism only and does not attempt to treat the problem of transmitted mental impressions or aptitudes. It is therefore far less controversial than Semon's first publication.

It opens with a chapter defining the subject and giving the essence of the mnemic theory in its general application, which forms an easy introduction for those readers to whom the doctrine is not familiar. Semon states that we see in an excitation and its manifestations as a sensation not two phenomena, but a single phenomenon contemplated from two different points of view. All synchronous excitations within an organism form a connected simultaneous complex, which acts engraphically and are an unanalysable whole. This he speaks of as an "energetic situation."

Any return, even in part, of this situation causes the revival of the engram complex or, as he called it, "ecphory." This is the basis of association, which Semon defines as "the result of an engraphy disclosed on the occasion of an ecphory" (or mnemic revival).

The individually acquired engram store is formed by engram complexes linked to one another in a continuous series. Each simultaneous complex goes to constitute a coherent unity, which is in close connection with that which preceded it. Successive association is thus only a secondary species of simultaneous association.

The only elements of any given content of consciousness are sensations; feelings are not specific elements, but shades of sensation. He denies the existence of single sensations, for every fresh excitation finds a complex situation, which of necessity modifies the mode of response.

Two sensations exist "side by side," when they are endowed with different spacial characters, whilst they fuse if they have the same local signature. This leads to the conception of fields of sensation. Every sensation appears in a particular field. The gate of stimulation through which an original sensation is admitted decides the locality of its "sensation field," and the same is true for mnemic revivals. When two original or two mnemic sensations arise in the same field and cannot be distinguished from one another, Semon speaks of "homophony" rather than fusion. The result is an increase of vividness rather than of intensity. This is true whether this meeting takes place between original or mnemic sensations, or between the two kinds together. Two sensations of one and the same kind entering through two different gates do not fuse, but are liable to compete with one another.

We have been able to touch on the main outlines only of Semon's theory, which is not only of general interest to the student of nervous and mental disease, but is of profound importance on account of the influence it has exerted on continental thought. This translation is on the whole satisfactory, and it will enable the English reader to find his way easily through the somewhat cumbrous nomenclature employed by Semon, and to grasp his philosophical conception of the nature of biological continuity.

It is preceded by a lively and interesting introduction by Vernon Lee, who was a friend of the author, and was greatly helped in her studies on the psychology of musical appreciation by his theoretical conceptions. This essay forms in itself a valuable and illuminating contribution to the discussion.

Die Funktionen des Stirnhirns: Ihre Pathologie und Psychologie. Von E. FEUCHTWANGER. (Monographien aus dem Gesamtgebiete der Neurologie und Psychiatrie.) Berlin: J. Springer. 1923.

The functions of the frontal lobes of the human brain have been a subject of much discussion since the conception of localization of cerebral function first arose. The main difficulty in attaining any reliable conclusions has been the scarcity of suitable material, and the unsatisfactory nature of that which is available in ordinary clinical work. It is, of course, not uncommon to meet cases with extensive lesions of vascular origin of one or both frontal lobes, but in most of these there is diffuse arteriosclerosis of the cerebral vessels, or patches of softening are present in other regions which complicate the necessary investigations or may falsify the deductions. Tumours of the frontal lobes are an even more unsatisfactory material to study, as the rise of intracranial pressure associated with them and the circulatory disturbances they frequently produce may interfere with the activities of other regions of the brain, and there is also the difficulty in ascertaining the exact extent of the local destruction they cause. The late war has, however, provided an extensive material on which these problems can be more satisfactorily studied, for gunshot wounds of the frontal lobes were common, and many men have

survived even extensive mutilations. It is on such cases that Feuchtwanger's investigations have been made.

It is impossible to deal with his methods, observations and conclusions in a review of this compass; it must suffice to draw the attention of those who are interested in the problem of the localization of function in the brain, or in the somatic or psychological symptomatology of its diseases, to a valuable contribution to these subjects.

Zur Physiologie und Pathologie des Skelettmuskeltonus. By E. A. SPIEGEL. Pp. 108. Berlin: Julius Springer. 1923.

The author gives a critical review of the different aspects of the problem of skeletal muscle tone, dealing successively with the development of the notion of tone and with its definition, the innervation of tonic contraction, its physics and biochemistry, its quantitative estimation and its variations in normal and pathological states of the nervous system. A lengthy bibliography indicates the sources to which he has gone. These appear to be predominantly German, and since the fundamental experimental observations upon which modern notions of muscle tone must rest are largely the work of the English school of physiology, it follows that his treatment of the different aspects of the subject is very unequal. This is especially true of the section dealing with the physiological significance of muscle tone and of those forms of hypertonus found in man in disease of the nervous system, which the English reader will find very disappointing. More interesting are the chapters dealing with the vexed question of a sympathetic innervation of muscle tone. From a review of the histological and experimental work of the Dutch observers, he concludes that we have at present no alternative but to hold that tonic and phasic innervation employ the same lower motor neurone—namely, that arising in the ventral horn cells of the spinal cord—and that the rôle of the sympathetic fibres which pass to the muscles is unknown.

Passing to the metabolic side of the question, he concludes that the small energy output associated with tonic contraction cannot be correlated with a special form of protein metabolism of which creatin is the characteristic end-product.

In accord with these findings are the results of electromyographic studies of phasic and tonic contraction. The action currents accompanying the two forms show no qualitative differences, varying in unimportant respects only.

Spiegel describes a method of estimating the degree of tonic resistance of a muscle to passive stretching, and expresses the results of his observations in a series of curves. According to whether tone is diminished (as in tabes dorsalis), or increased (as in pyramidal spasticity and in paralysis agitans), so the curves take on characteristic forms. The resistance in question is analysed more or less adequately on the lines of Sherrington's views as to the nature and significance of plastic tone. The author appears to draw no distinctions between Parkinsonian rigidity and pyramidal spasticity, and despite the work

of Magnus and de Kleijn, which he quotes, holds the view that the proprioceptive reflex are concerned in the maintenance of muscle tone passes through the cerebellum.

Die extrapyramidalen Erkrankungen mit besonderer Berücksichtigung der pathologischen Anatomie und Histologie und der Pathophysiologie der Bewegungsstörungen. By Dr. A. JAKOB. S. 399 mit 167 Textabbildungen. Berlin: J. Springer. 1923. Price 7.20 dollars.

The author's lengthy monograph embodies the results of a careful histological examination of over sixty cases of disease of the basal ganglia. In this series every clinical variety of extrapyramidal syndrome and a large number of disease processes are represented. Detailed clinical and pathological case records are given and the lesions found are beautifully illustrated by over 160 photographs. A large part of the monograph is devoted to extensive résumés of the very numerous clinical, pathological and experimental researches on the corpus striatum of the past decade. These, which cover many pages of small print, are difficult to follow owing to their conciseness and break up the author's own observations in a most exasperating manner. The literature on extrapyramidal diseases has become too copious for each new worker to attempt to summarize it when presenting his own results. Moreover, it may be assumed that the reader of such highly specialized subject matter is acquainted with the main lines of thought involved.

Jakob concludes with an extensive analysis of the various syndromes with reference to their bearing on the normal functions of the basal ganglia, and there are sections dealing seriatim with the functions of the cerebellum striatum, pallidum, thalamus, hypothalamus, corpus Luysii and substantia nigra. However, no clear distinction appears to have been drawn between the localization of symptoms in disease of these structures and that of normal function in the intact brain.

Zur Klinik der nichtparalytischen Lues-psychosen. Von H. FABRITUS. S. 103. Berlin: S. Karger. 1924.

In this monograph the author has described in considerable detail and analysed carefully the symptoms of twenty-three cases of psychoses that could, in all probability, be attributed to syphilitic infection, but were not due to dementia paralytica. He classifies these cases in four groups: In the first, the exogenous reaction types, he includes confusional and demented states which often run a rapid course. The second group contains the hallucinatory and paranoid types which are closely allied to the first class. In the third group, the chronic defect states, he includes syphilitic pseudoparalysis and post-syphilitic dementia, while in the fourth group he places various maniacal-depressive and catatonic states.

The monograph is an interesting and valuable contribution to the clinical study of not uncommon conditions that frequently give considerable trouble in diagnosis.

Beitrage zur Entwicklungsgeschichte des menschlichen Gehirns. II Teil, 2te Lieferung: *Die Entwicklung des Hirnanhanges.* Von Prof. F. HOCHSTETTER. Wien und Leipzig: Deuticke. 1924.

Hochstetter's last contribution to the development of the brain was devoted to the pineal body; the present monograph deals with the growth of the hypophyses. It is chiefly concerned with the development of the human hypophysis, but this is studied in various other mammals too. In most of these there are definite differences in the mode of its growth as compared with that of man.

The interest of the author's description is mainly anatomical. The monograph is liberally illustrated by a large number of figures in both the text and in plates; some of these are diagrams, others photomicrographs or drawings of sections or of wax models, of various stages of the evolution of the pituitary region.

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EDITOR.